Advance News on Twelfth Annual NACE Conference, Page 75

Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS

Vol. 12 FEBRUARY, 1956 No. 2

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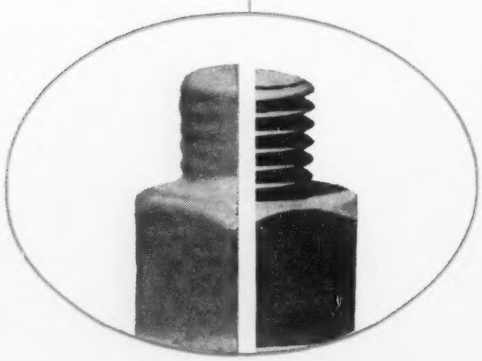

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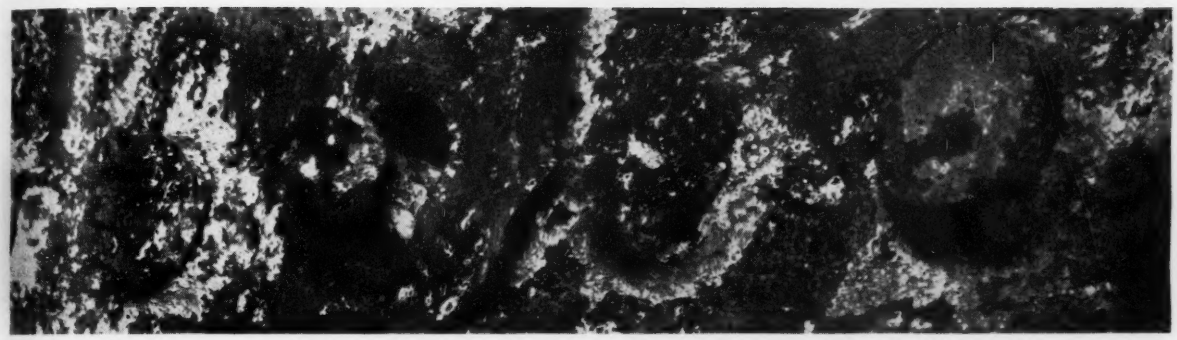

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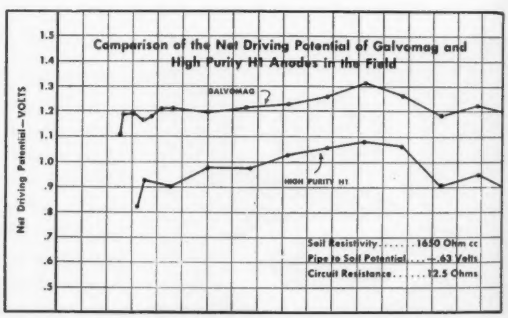

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THIS MONTH'S COVER—Members of the NACE committee making arrangements for the NACE Conference March 12-16 in New York examine an 1800-year-old piece of lead pipe manufactured during the reign of Roman Emperor Vespasian 69-79 AD. Excavated in 1907, the pipe is still in usable condition. It was loaned by National Lead Company and is inscribed "IMP CAES AUG VESPASIANA SUB CURA CALLISTI AUG L PROCURATORIS."

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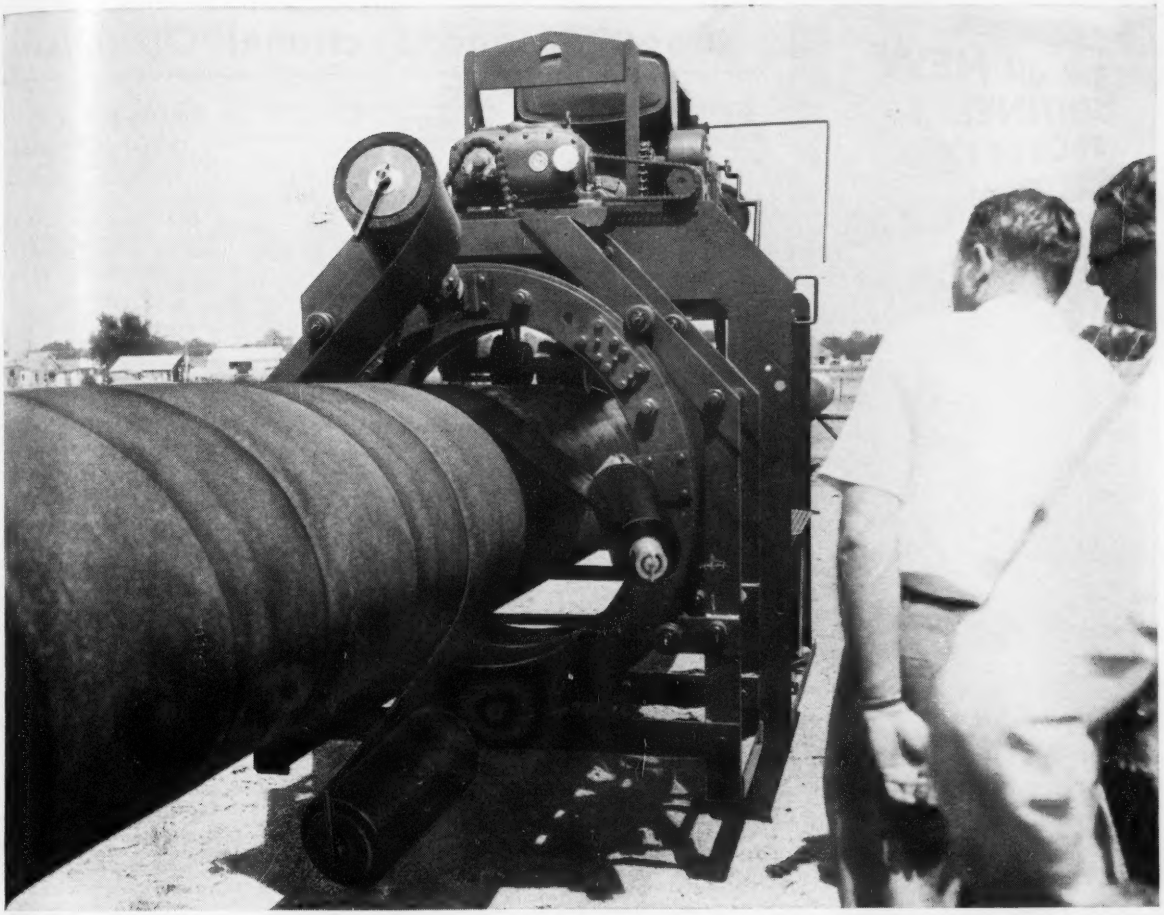

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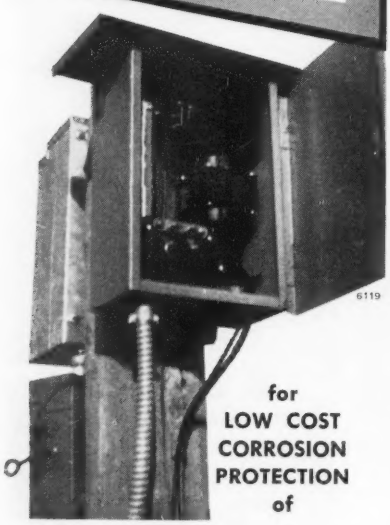

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Directories of Regional and Sectional Officers and Technical Committees are run on alternate months. Look for Directory of Technical Committees next in March and next running of regional and sectional officers in April issue. Early notice of changes will permit keeping these directories up to date.

BACK ISSUES OF VOLUME 11

Copies of back issues of Volume 11, January-December, 1955 are available except July. Persons who customarily bind all or parts of Corrosion and who lack issues to make the volume complete may get back copies at the following prices per copy, postpaid, remittance in advance: NACE members, 50 cents; Non-members, $1. An additional charge of 65 cents per package is made for mailings to addresses outside the United States, Canada and Mexico.

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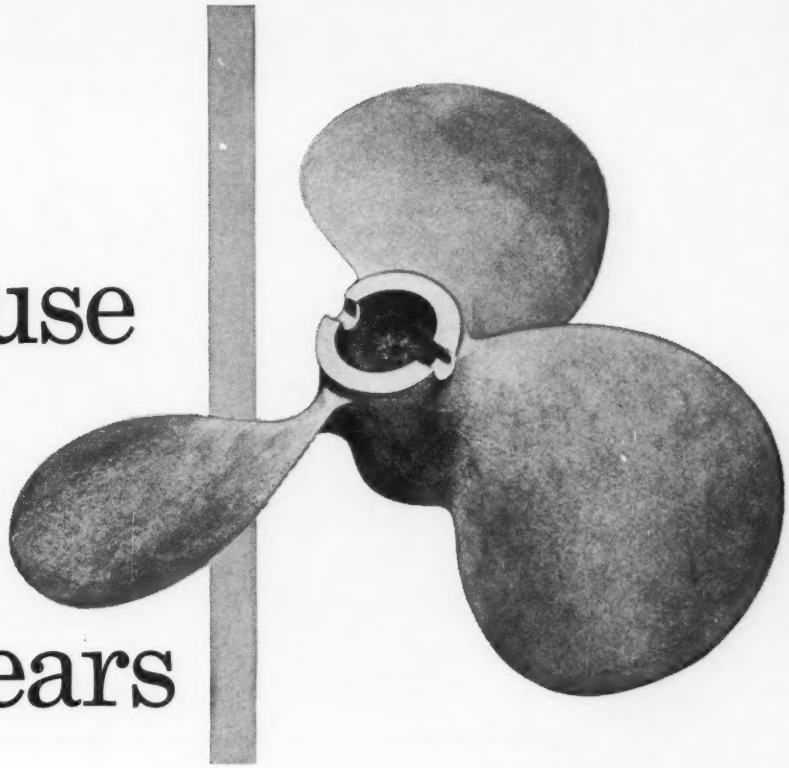

in hot sulphuric acid and chlorides

PROBLEM.... Agitator propellors were failing at a rate of one every three months in dye kettles where hot sulphuric acid was mixed with chlorine-bearing organic chemicals. Sometimes corrosion was so severe that the propellors fell off the shaft and chipped the kettle lining. This required a major overhaul.

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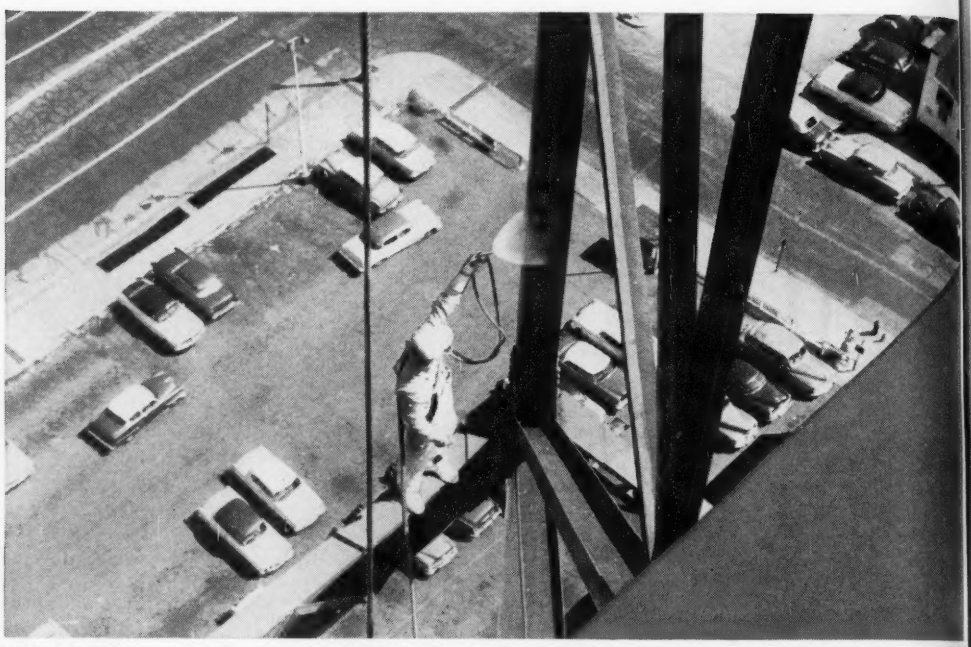

Without clearing area below, a Hanks' painter sprays 550' radio tower.

In painting towers or tanks, refineries or plants—noted contractor reduces costs with DeVilbiss equipment, states . . .

Stanley Hanks

"Spray mist no longer a problem"

In the immediate area are offices, stores, truck terminals, and over 1000 parked cars. Yet – using two DeVilbiss MBC Spray Guns – five of Stanley Hanks' painters climbed this 550-ft. radio tower, painted it in alternating 40-ft. strips of white and orange . . . without a single damage claim from spray mist!

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Close-up of painter spraying radio tower with Phelan's SAFE-T-SPRAY

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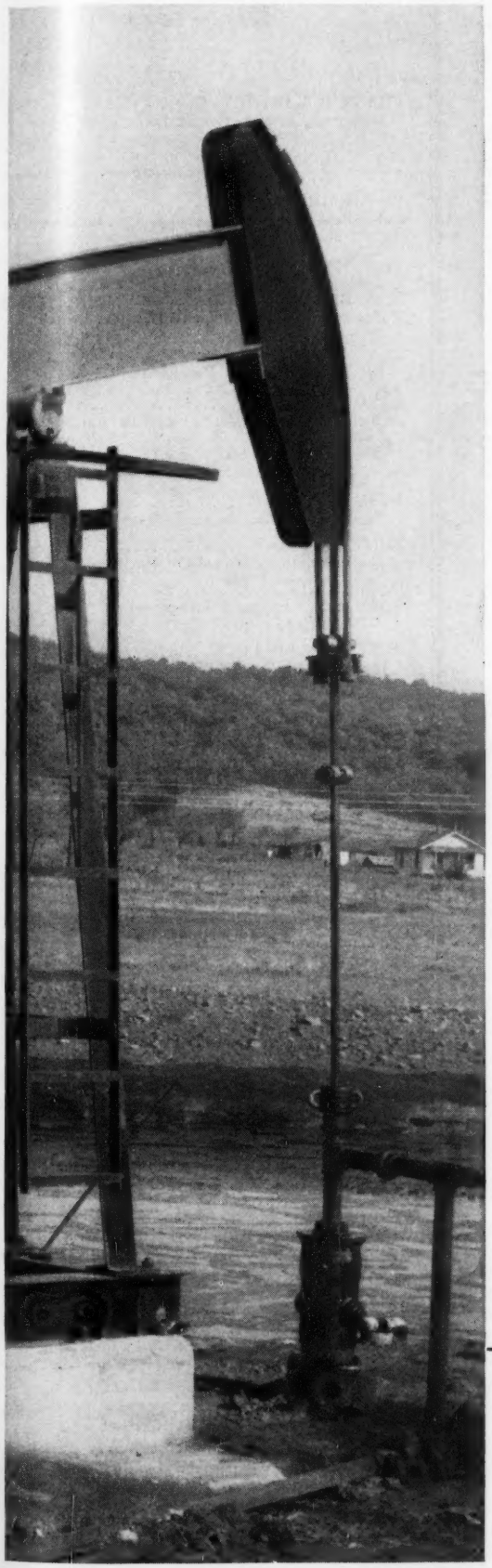

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(a) To promote the prevention of corrosion, thereby curtailing economic waste and conserving natural resources.

(b) To provide forums and media through which experiences with corrosion and its prevention may be reported, discussed and published for the common good.

(c) To encourage special study and research to determine the fundamental causes of corrosion, and to develop new or improved techniques for its prevention.

(d) To correlate study and research on corrosion problems among technical associations to reduce duplication and increase efficiency.

(e) To promote standardization of terminology, techniques, equipment and design in corrosion control.

(f) To contribute to industrial and public safety by promoting the prevention of corrosion as a cause of accidents.

(g) To foster cooperation between individual operators of metallic plant and structures in the joint solution of common corrosion problems.

(h) To invite a wide diversity of memberships, thereby insuring reciprocal benefits between industries and governmental groups as well as between individuals and corporations.

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Corrosion

OFFICIAL MONTHLY PUBLICATION

National Association of Corrosion Engineers

An Association of Individuals and Organizations Concerned with Control of Corrosion

1061 M & M Building Houston 2, Texas

Vol. 12 FEBRUARY, 1956 No. 2

Topic of the Month

Selective Corrosion of Delta Ferrite In Cast Stainless Steel

By J. M. BIALOSKY*

A PROBLEM involving the localized corrosion of cast stainless steel in a Simplex Dispersator was referred to the writer. The Dispersator had been operated in a mixture of an organic liquid and water during the neutralization of an acid catalyst with caustic soda solutions and during subsequent water washing operations.

Figure 1 shows the Dispersator and a portion of the shaft. The unit consisted of a flanged hub casting, a body casting and an internal sheet metal vane. The back portion of the body casting had been cut away and the vane had been removed prior to photographing in order to show the perforations.

The shaft and the sheet metal vane conformed to AISI Type 304 stainless steel and the hub and the body castings conformed to ACI CF8 as specified. Analytical results are given in Table 1.

TABLE 1—Chromium and Nickel Content of Dispersator Parts

PART	Percent Cr	Percent Ni	Magnetic
Shaft	18.05	9.05	No
Vane	18.38	8.78	No
Hub Casting	18.89	7.89	Slight
Body Casting	19.54	8.09	Slight

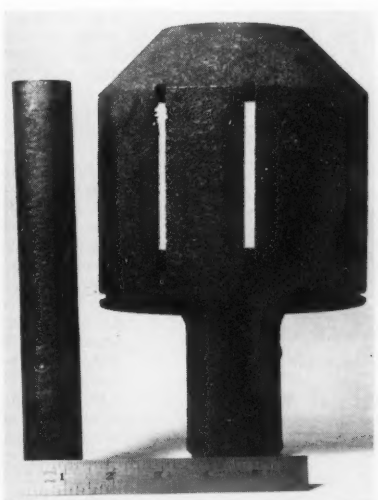


Figure 1—Wrought Type 304 stainless steel shaft (left) and cast Type CF8 Alloy Dispersator.

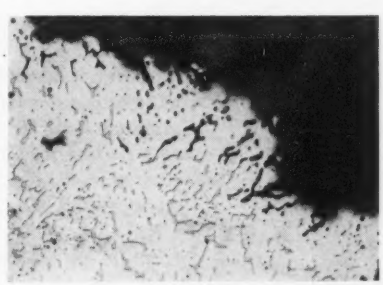


Figure 2—Microstructure through surface of body casting showing selective attack on delta ferrite phase. Electrolytic oxalic acid etch. 58X.

Type 304 stainless steel specimens exposed in this environment exhibited corrosion rates of 0.001 and 0.002 ipy with no evidence of pitting or localized attack. The slight roughening observed on the shaft and the appearance of the vane tend to confirm the results of the corrosion tests, although the severe roughening and perforation of the cast parts was not in agreement with the test results.

Metallographic specimens were prepared of the body casting (see Figure 2.) The second phase which may be observed in the structure is delta ferrite which is formed at high temperature. This phase is responsible for the magnetic characteristic of the metal. The delta ferrite had been preferentially attacked by the environment and this resulted in deep pits. It is believed that the local perforations resulted from crevice corrosion initiated by these pits.

In order to prevent future occurrence of this type of attack, it was recommended that the nickel content of the casting be specified on the high side of the allowable range, thereby minimizing the amount of delta ferrite present in the alloy.

* Koppers Company, Inc., Research Department, Verona, Pa.

59t

A Study of Protective Criteria on a Pipe Section in a Uniform Environment*

By L. P. SUDRABIN

Introduction

THE MEANING of a pipe to reference electrode potential measurement, on a cathodically protected pipeline, is dependent upon the location of the reference electrode in relation to the pipeline. It is the purpose of this investigation to demonstrate the relationship between the reference electrode position and the potentials measured on a pipeline section under freely corroding and cathodically protected conditions, respectively. It is intended, this be done with predetermined anodic areas in a uniform environment.

The need for a better understanding of cathodic protection criteria is illustrated by the all too frequent inclination to adopt only a single criterion practice for all instances; for example: pipe to reference electrode over pipe, pipe to remote reference electrode, pipe to polished steel bar, earth current meter, break in potential—log current density relationship, etc. Each of these criteria will assure corrosion control for some specific forms of corrosion; in other instances, they will have little or no meaning.

An analysis was made of 136 replies to a questionnaire prepared in 1948 by the NACE Committee T-4 (now T-2C) "Minimum Current Requirements for Cathodic Protection."[1] The purpose of this study was to determine whether there was a proven procedure to establish the effectiveness of cathodic protection and whether there were criteria which would establish the minimum current density requirements. The following opinions were reached as a result of this analysis:

1. No thoroughly proven criterion for cathodic protection exists.
2. Minimum current requirements probably are variable from place to place and from time to time.

Investigation Conditions

The experimental program to demonstrate the relation of the reference electrode position to freely corroding and cathodically protected conditions was organized intentionally to allow measurement of all the electrical elements involved. Although the model pipe section used did not duplicate all the absolute conditions found on corroding and cathodically protected pipelines, it did include the basic spatial, environmental and electrical elements that exist. The corrosion current flow between the anode and cathode could be measured in the metallic closure circuit and the potential gradient in the resistive media surrounding the pipeline could be determined.

★ Submitted for publication January 31, 1955. A paper presented at the Eleventh Annual Conference, National Association of Corrosion Engineers, Chicago, Illinois, March 7-11, 1955.

L. P. SUDRABIN—Director of Engineering Services and Development of Electro Rust-Proofing Corporation, Belleville, N. J. He graduated from Northeastern University, Boston, in 1936 with a BS in chemical engineering. Prior to joining Electro Rust-Proofing, Mr. Sudrabin occupied the positions of research engineer with the Dorr Company, chief chemical engineer with Dayton Power and Light Company and chemist with the Boston Edison Company. He has been a member of NACE since 1944 and is chairman of Unit Committee T-2C on Minimum Current Requirements for Cathodic Protection as well as being a member of several other NACE technical committees.

Abstract

The effect of the reference electrode location upon the meaning of the pipe to reference electrode potential is demonstrated by use of a model pipe section. Known anodic areas of representative shape and position are established on iron pipe by coupling high purity zinc plates through measuring circuits.

It is found that the protective potential gradient, including the (IR drop) potential effects the system is entitled to, moves farther from the pipeline as the lines of corrosion current flow increase in length. Another finding is that the potential gradients of the smaller local corrosion cells are not discernible by surface potential measurements.

The following generalizations for establishing the effectiveness of protective current on bare pipe have support:

1. Long line corrosion currents are controlled when the protective potential (—.85 volts) is measured to a Cu-$CuSO_4$ reference electrode in a remote location (100 feet away or further from pipeline). Intermediate and local cell corrosion currents are reduced.
2. Long line and intermediate corrosion currents are controlled when the protective potential is measured to a reference electrode placed over the pipeline. Local cell corrosion currents are reduced.
3. Long line, intermediate and local cell corrosion currents are controlled when the protective potential is measured close to the pipe surface.

Measurements 1 and 2 are critical to stray current, shielding and anode potential gradient effects.

The anodic areas of representative shape and position were established on the iron pipe section by attaching insulated zinc plates to the pipe. Lead connections were attached to the zinc and the iron pipe to facilitate measurement of current, potential and resistance. The entire pipeline section assembly was placed into an all wood tank 8 feet high, 8 feet wide and 8 feet deep which contained water (see Figure 1).

The standard 3-inch pipe (3.50-inch o.d.) eight feet in length used to represent the cathode was pickled, rinsed and lightly sanded. Three No. 16 insulated lead wires (terminals 1, 2 and 8) were attached to

the pipe for coupling to the zinc, to the potential test connection and for application of protective current.

The anodic areas were prepared from high purity $\frac{3}{16}$-inch thick zinc plate containing .0009 percent Pb and .0003 percent Fe—a plate furnished by the New Jersey Zinc Company. Two anodes were cut from the master sheet and bent to conform to the 3-inch pipe curvature:

(ZN - A) 1-inch diameter disk
(ZN - B) 1½-inch x 12-inch plate

Two No. 16 insulated lead wires (terminals 3, 4 and 6, 7) were soldered to each zinc anode. The surface of the zinc contacting the 3-inch pipe was covered with .010-inch scotch electrical tape. The disk and plate anodes were attached firmly to the pipe 3 feet from each end of the pipe and positioned 180 degrees from each other.

The pipe section, including the attached zinc anodes, was lowered into the water and positioned horizontally at a depth of 12 inches using a Saran rope hitch on each end of the pipe section. The pipe section could be rotated as required. The spatial relations in this study conformed closely to 6-inch pipe buried 24 inches and 9-inch pipe buried 36 inches.

The protective current was applied to terminal 9 (a 1-inch diameter x 8-foot aluminum anode located in the bottom of the wooden tank).

A movable saturated KCl calomel reference electrode with a saturated KCl bridge (7 mm bore x 60 cm length stylus tipped glass tube) was used to probe for the potential gradient around the pipe. All potentials were measured with a potentiometer. Three-inch Weston 0-1 ma and 0-5 ma panel meters were used to measure the net corrosion current between terminals 2-3 and/or 2-4.

Belleville, New Jersey, tap water resistivity (ρ — 12,400 ohm-cm) was used in the initial tests. Sodium chloride was added to lower the water resistivity ρ — 2690 ohm-cm for later tests.

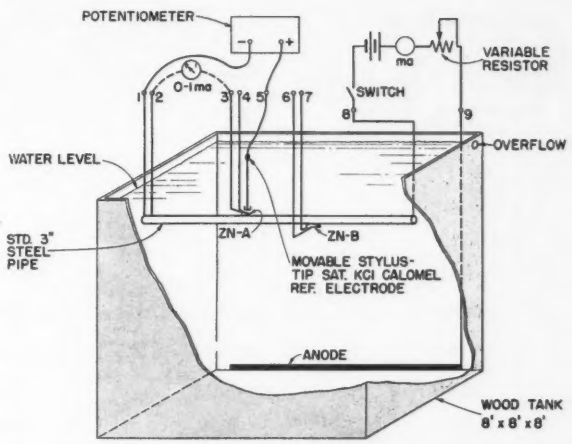


Figure 1—Model pipe section test assembly arrangement.

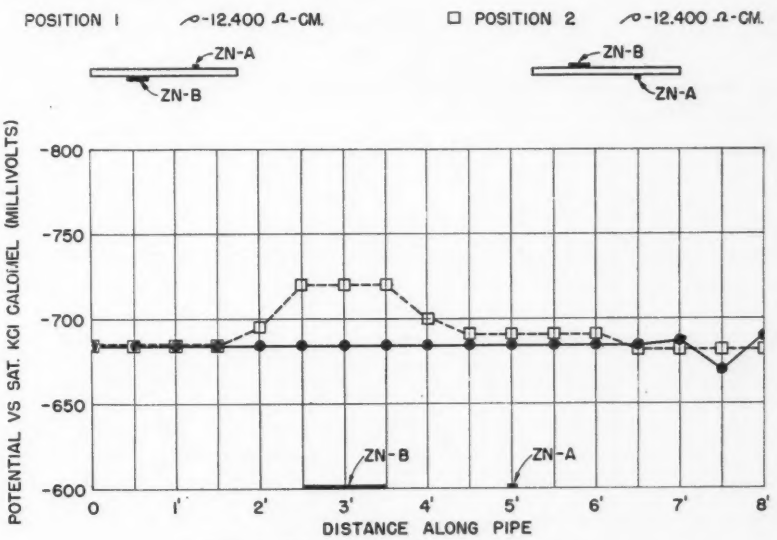


Figure 2—Potential gradient on water surface.

Open Circuit Potentials

The open circuit potentials of the uncoupled zinc anodes (ZN-A and ZN-B) and iron pipe cathode were measured separately against the reference electrode placed on the surface of the water over the pipe section.

The absence of a discernible potential gradient when the reference electrode was moved closer to the zinc anodes and the iron pipe indicates that there were no large discrete anodic and cathodic areas on the respective metal surfaces. The open circuit potentials observed represent the net effect of the very small anodic and cathodic areas on the zinc and iron electrode surfaces.

Corroding System Potentials

The representation of a pipeline corrosion system with anodic areas (ZN-A and ZN-B) was placed into effect by bonding terminals 2-3 and 2-6 through milliammeters, respectively. The potentials on the surface of the water (ρ — 12,400 ohm-cm) over the pipe axis were measured. In Figure 2, position 1, (ZN-A) is on top of pipe and (ZN-B) on bottom of pipe; for position 2, the pipe was rotated 180 degrees.

The effects of anode (ZN-B) were noted only when it was in position 2. Very little effect was observed on the water surface of the coupled anode (ZN-B) in position 1 or of coupled anode (ZN-A) in positions 1 and 2. The potential gradient about anode (ZN-A) was determined by coupling terminals 2-3 only and probing with the stylus tipped reference electrode

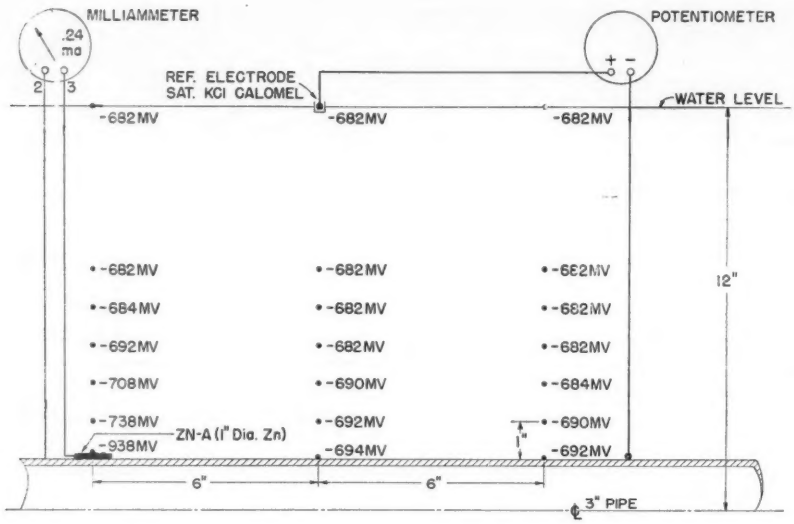


Figure 3—Potential gradient—local cell corrosion.

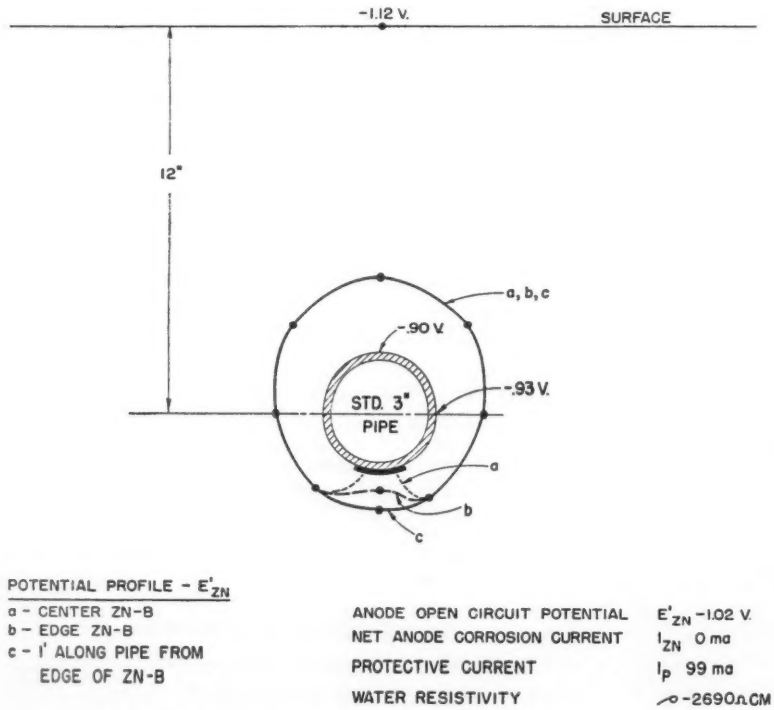


Figure 4—E'_{ZN} potential gradient (ZN-B Position 1).

(see Figure 3). The effect of this 1-inch diameter anode was not distinguishable at a distance of 5 inches above the surface of the pipe. Similar potential gradient patterns were observed in more conductive water (ρ — 2690 ohm-cm).

Protected System Potentials

Protective current was applied to terminals 8-9 (Figure 1) until the net current flow between terminals 2-3 and/or 2-6 coupled to the iron pipe through a milliammeter were zero. In each instance it was found that more protective current was required to accomplish such control with the small anode (ZN-A) than with (ZN-B). An example of this is shown in Table 1.

The potential gradient equivalent to the open circuit potential for the zinc anode was established at zero zinc anode current flow conditions.

Figures 4 and 5 illustrate the location of the equipotential gradient corresponding to the open circuit potential of the larger anode (ZN-B) on the iron pipe section in positions 1 and 2 respectively. The potential gradient was established around the 1½-inch x 12-inch anode (ZN-B) and the 3-inch pipe section at:

(a) Three feet from the end of the pipe (center ZN-B)
(b) Three and a half feet from the end of the pipe (edge of ZN-B)
(c) Four and a half feet from the end of the pipe (1 foot from the edge of ZN-B).

The potential gradients 90 and 180 degrees around the pipe from anode (ZN-B) are similar at locations (a), (b) and (c). At location (a), the potential gradient intersects the (ZN-B) anode surface. The potential gradient indicates flow of protective current into the center area of the zinc anode (ZN-B) when the net current flow measured in the metallic closure circuit between the anode and the pipe is zero. The significance of this anomaly is considered in the discussion.

Figure 6 shows the location of the equipotential gradient corresponding to the open circuit potential of the smaller anode (ZN-A) on the iron pipe section in position 1 when the net anode corrosion current flow is zero. The equipotential gradient position in relation to the pipe varied little in 2690 and 12,400 ohm-cm waters, respectively.

The potentials observed on the water surface over the pipeline in Figure 4 (—1.12V), Figure 5 (—1.20V) and Figure 6 (—1.52 and —1.55V) are more electronegative than the open circuit potentials of the zinc

TABLE 1—Relation of Protective Current and Corrosion Current Control of Local Anodes

I (Protective)	I (ZN-A)	I (ZN-B)
0 ma	.657 ma	4.87 ma
95 ma	.205 ma	0.0 ma
170 ma	.000 ma	—0.740 ma

anodes. The more electro-negative potentials (—1.52 and —1.55V) are required at the water surface to control the net corrosion current flow out of the smaller anode (ZN-A).

Subsurface Potential Calculation

The potential of the pipe to a reference electrode positioned close to pipe surface is difficult to measure underground. The potential of the pipe to a reference electrode close to its surface can be calculated from ground surface potential measurements and knowledge of the physical dimensions, current applied and soil resistivity.

This relationship is based upon the superposition of the image effect upon the potential of the pipe to its environment[2] (See Equation 1 below).

$$E_r = E_s + .012\,\rho I\left(\log\frac{d}{r} - \log\frac{2d-r}{d}\right)$$

Where:

E_r = potential of pipe to reference electrode over pipe at a distance "r" from the pipe axis (millivolts).

E_s = potential of pipe to reference electrode over pipe at soil or water surface (millivolts).

ρ = soil restivity ohm-cm.

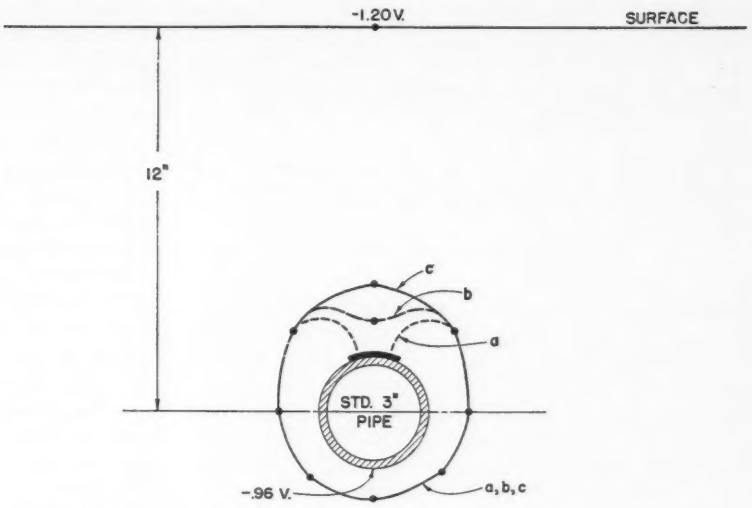
d = depth of burial in feet.

r = assumed reference electrode location (E_r) distance in feet from center axis of pipe.

I = protective current ma per lineal foot of pipe.

This equation is used to calculate the pipe to reference electrode potential, at the protective potential gradient, from the water surface potential measurements made in Figures 4, 5 and 6. A comparison of the observed potential and calculated values is shown in Table 2.

Howell[3] showed that the current (I) can be calculated from the ground surface gradient normal to the pipeline in the following manner:

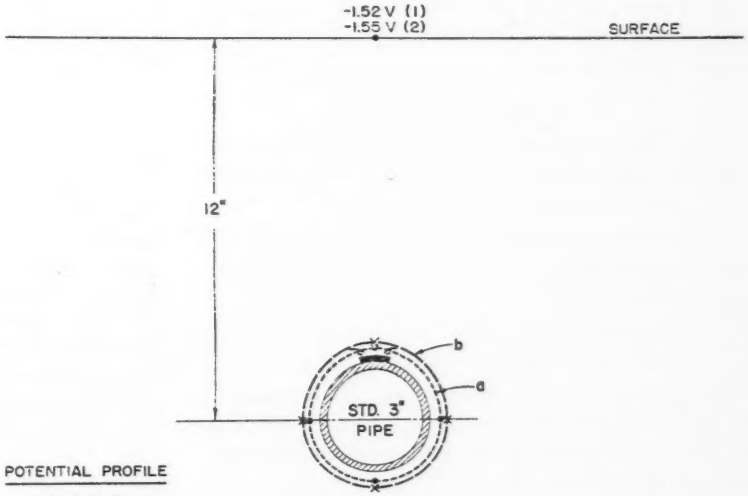


POTENTIAL PROFILE - E'_{ZN}

a - CENTER ZN-B
b - EDGE ZN-B
c - I' ALONG PIPE FROM EDGE OF ZN-B

ANODE OPEN CIRCUIT POTENTIAL	E'_{ZN} -1.02 V.
NET ANODE CORROSION CURRENT	I_{ZN} 0 ma
PROTECTIVE CURRENT	I_p 148 ma
WATER RESISTIVITY	∽ 2690Ω CM

Figure 5—E'_{ZN} potential gradient (ZN-B Position 2).



POTENTIAL PROFILE

a - CENTER ZN-A
b - I' FROM CENTER ZN-A

	1	2
ANODE OPEN CIRCUIT POTENTIAL	× E'_{ZN} -.99 V.	• E'_{ZN} -1.05 V.
NET ANODE CORROSION CURRENT	I_{ZN} 0 ma	I_{ZN} 0 ma
PROTECTIVE CURRENT	I_p 65 ma	I_p 250 ma
WATER RESISTIVITY	∽ 12,400Ω CM	∽ 2690Ω CM

Figure 6—E'_{ZN} potential gradient (ZN-A Position 1).

TABLE 2—Protective Potential Gradient (Calculated and Observed)

E_s	ρ-ohm-cm	d	r*	I ma/ft	E_r (Calc)	E_r (Observed)
—1.12V	2690	1.0′	.326′	12.4	—1.014V	—1.02V
—1.20V	2690	1.0′	.266′	18.5	—1.025V	—1.02V
—1.55V	2690	1.0′	.183′	31.6	—1.065V	—1.05V
—1.52V	12,400	1.0′	.190′	8.15	—0.970V	—0.99V

* (r) is measured at location (c).

$$I = \frac{42\,e}{\rho} \qquad (1a)$$

Where:

$e = \frac{e_1 + e_2}{2}$ = average surface voltage drop for spacing of ten pipe depths normal to the pipeline, millivolts.

The potential gradient E_r to the pipe surface is established by measurement of only E_s and e at each test location as expressed in Equation (1b):

$$E_r = E_s + .5e\left(\log\frac{d}{r} - \log\frac{2d - r}{d}\right) \qquad (1b)$$

The accuracy with which the subsurface potential can be calculated is limited by the uniformity of the soil and the reliability of the data used. Since Equations (1), (1a) and (1b) are derived by the superposition of the image effects of line electrodes, the actual round pipe will not conform to the calculated potential gradient. These approximations become more valid as the ratio of burial depth/pipe diameter increases.

The subsurface potential calculation method is particularly helpful in interpreting the significance of ground surface potential measurements. Remote, ground surface and close to pipe surface potentials approach one another if: (1) the soil resistivity is low and (2) the protective current requirements are low (this is because a resistive coating on the pipe surface or polarization is readily achieved). Shielding by other pipelines and protective anode system potential gradients must be considered when use is made of Equation (1) or (1b).

Fundamentals

Among the conditions required to approach complete corrosion control by cathodic protection on a corroding metal surface are:[4]

1. The current flow into the corroding media at the anodes must become zero.
2. The cathodes must be polarized to the open circuit potential of the anodes. (See Anode open circuit potential.)

The protective potential (E'_a open circuit potential of the anode) and the equivalent cathode potential, when the corrosion current at the anode is zero, can be expressed by the equation:

$$E'_a = E_c + I_p\,(R_{cf} + R_{kc\rho}) \qquad (2)$$

Where:

E_c = potential of cathode including polarization effects which are a function of current density and time.
I_p = protective current.
R_{cf} = cathode film resistance.
$R_{kc\rho}$ = resistance of cathode electrolytic component (characteristic for corrosion system and electrolyte resistivity).

The I_p ($R_{kc\rho}$) potential effect often represents a large part of the total cathode polarization to which the cathodically protected system is entitled. This has been demonstrated previously by use of a model corrosion system.[5]

The I_p ($R_{kc\rho}$) potential cathodic polarization effect is characteristic of each cathodically protected system. It is observed also that the corrosion current flow decreases as the protective current flow increases.

Length of Corrosion Current Flow Lines

The size and spatial relation of the corroding anode and cathode areas determine the distribution and length of corrosion current flow lines through the soil surrounding a pipeline.

Because of the fact that the ratio of the soil/pipe metal resistivities range from 10 to the eighth to 10 to the ninth, the lines of corrosion current flow are normal to the metal surface. Lines of corrosion current flow do not cross each other.

At the junction of anodic and cathodic areas, Copson[6] has demonstrated that the lines of corrosion current flow are short and the current density is high. The lines of corrosion current flow become longer and the current density lower at increasing distances from the junction.

The lines of the protective current flow also are normal at the metal surface. Pearson,[7] using the principle of superposition, proposed the idea that the net current effect at the metal surface is the vector sum of the corrosion current and protective current. If one could identify a single flow line of corrosion current, one would see that the net current flow into the anode was zero at the protected condition and the current flow into the cathode was equal to the protective current. The cathode polarization is entitled to the potential drop through an electrolyte column, normal to the pipe, equal to the maximum distance of the trajectory of the specific corrosion current flow line from the pipe.

In order to obtain complete control of the short lines of corrosion current flow associated with a localized pit or at the boundary of extensive anode and cathode areas, the length of electrolytic path of the element ($R_{kc\rho}$) that the criterion condition 2 (Equation 2) is entitled to is short and the protective potential must be measured close to the metal surface.

Long line corrosion currents are more easily controlled than localized pitting because they are entitled to the longer electrolytic path for the element ($R_{kc\rho}$).

Anode Open Circuit Potential

The value of the open circuit potential of the iron anode to which the cathode polarization must be made equivalent has not been established too clearly. Some experiments by Schwerdtfeger and McDorman[8] and reference citations by Gatty and Spooner[9] have shown that iron in an air-free environment of pH 9.0 corrodes at a negligible rate. Iron electrodes under these conditions have been measured to have a potential of —.77 volts to a saturated KCl calomel reference electrode (—.85 volts to a Cu-$CuSO_4$ reference electrode). Experience over many years has indicated that piping systems are protected when the potential measured against a Cu-$CuSO_4$ reference electrode is —.85 volts.[10]

Schwerdtfeger and McDorman[8] also noted that the

potential of iron measured against the reference electrode became less electro-negative as the pH of the air-free environment decreased (for example, —.73 volts to a saturated KCl calomel reference electrode at a pH of 5.0). This observation coupled to the very low pH sometimes noted in active pit corrosion products[11, 12] should be considered in the interpretation of natural corrosion potential data.

The author has observed iron to saturated KCl calomel potentials of —.77 volts in air-free sea water[12] and in silt 130 feet below the Hudson River surface.

Discussion

The interpretation of bare pipe to reference electrode potential measurement must be related to the length of galvanic corrosion current flow lines occurring on the pipeline.

Long Line Galvanic Corrosion Current.

A pipeline behaving as a closure circuit between widely spaced anodic and cathodic areas furnishes an example of long line galvanic corrosion current. Long line current flow is identified by conventional ground surface potential gradient measurement and/or pipeline current flow techniques.

Intermediate Galvanic Corrosion Current

An example of intermediate galvanic corrosion current is to be found in the corrosion current flow in a system of anodic and cathodic areas whose ground surface potential gradient is discernible to a reference electrode positioned at (1 foot or greater) intervals along the pipeline.

Local Cell Corrosion Current

An example of local cell corrosion current can be found in the corrosion current flow in a system between anodic and cathodic areas whose ground surface potential gradient is not discernible to a reference electrode; i.e., the electrical boundary of the corrosion current flow line is close to the pipe surface.

The pipe to reference electrode potential observed includes the vector summation of the effects of long, intermediate and local cell corrosion currents. The local cell corrosion current may not be discernible and must always be "suspect" (see Figures 2 and 3). Such local corrosion cells may exist on surfaces indicated to be cathodic by ground surface potential gradient measurement.

Examples of local cell corrosion include:

Case 1. A 72-inch steel water main in northern New Jersey had been buried in a marsh. During backfilling, the overlying peat had been distributed throughout the clay surrounding the pipe. Localized pits, randomly positioned over the pipe surface, were associated with the areas of peat contact. The potential gradient on the ground surface (ρ — 6000 ohm-cm) indicated the 600 feet of pipe in the marsh area anodic to adjoining pipe. Intermediate and local cell corrosion currents were not identifiable by ground surface gradient (pipe cover 10 feet). The flow of corrosion current in the pipeline closure circuit at both ends of the 600-foot pipe section represented less than 25 percent of the equivalent corrosion experienced.

Case 2. Leaks had occurred on a bare unprotected pipeline in high resistivity sand (— 30,000 ohm cm *dry*, 50,000 ohm-cm after rain) within 3 years after construction.[13] In the areas of corrosion activity, small masses of talc-like consistency were found distributed throughout the sand.

At this location, experience had shown that the potential of the pipe to a Cu-$CuSO_4$ reference electrode placed on the ground surface over the pipe would have to be maintained more electro-negative than —.95 volts by means of a rectifier-anode system.

The pipe to reference electrode potential measured in Case 2 included a (IR drop) potential effect, a small part of which was really effective in the cathode polarization of the local cells.

Studies reported by Miller[14] showed that the flow of galvanic corrosion current between anode and cathode pipe sections spaced 12 to 45 feet apart was controlled when the open circuit potential of the anode was observed at a remote location. The potential measured against a reference electrode 1 inch and 30 inches from the cathode pipe section was found to be less electro-negative than at the remote electrode position.

Schwerdtfeger[15] has shown recently that geometric factors should be given consideration in making potential measurements of subsurface structures.

A comparison of data obtained on the cathodically protected model pipeline section (Figure 1) and shown in Table 1 and Figures 4, 5 and 6 leads to the following observations:

1. Less protective current is required to control the *net* corrosion current flow from the large anode (ZN-B) than from the small anode (ZN-A).
2. The cathode polarization is entitled to a potential drop through a 5 x longer electrolytic resistive path between reference electrode and pipe for anode (ZN-B) than for anode (ZN-A).

The protective current requirements (Table 1) are large in relation to the corrosion current because the galvanic system exhibits "mixed control" characteristics. "Anodic control"[16] becomes more dominant as the anode size decreases and/or the resistivity of the electrolyte increases.

Although the *net* corrosion current flow has been controlled (I_{zn}=O) it is seen that the potential gradient equivalent to the open circuit potential (line a, Figures 4 and 5) intersects the anode (ZN-B). This indicates current flow from the bulk of the water to the central area of (ZN-B), while there is short line corrosion current flow from the edges of (ZN-B) to the adjoining iron pipe. The long line current from the center of (ZN-B) will be controlled when the protective potential is observed at some greater distance from the pipeline than line c. The short line current flow at the junction of the corrosion couple will be controlled when the protective potential is observed at the pipe surface.

The special case of soil parting from the pipeline must be recognized as influencing the meaning of pipe potential measurement.

Conclusion

The value of —.85 volts measured against a Cu-

$CuSO_4$ reference electrode has general acceptance as the protective potential for iron.

The importance of the reference electrode location in relation to the pipe upon the protection achieved has had no standard acceptance.

It has been demonstrated in cathodic protection that the cathodic polarization is entitled to an (IR drop) potential gradient through the resistive soil surrounding the pipe. This potential gradient, to which the protective potential is entitled, is determined by the maximum trajectory of the specific corrosion current flow line to be controlled from the structure being protected.

The following generalizations for establishing the effectiveness of cathodic protection on bare pipe have support:

1. Long line corrosion currents are controlled when the protective potential (—.85 volts) is measured to a Cu-$CuSO_4$ reference electrode in a remote location (100 feet away or further from pipeline). Intermediate and local cell corrosion currents are reduced.
2. Long line and intermediate corrosion currents are controlled when the protective potential is measured to a reference electrode placed over the pipeline. Local cell corrosion currents are reduced.
3. Long line, intermediate and local cell corrosion currents are controlled when the protective potential is measured close to the pipe surface.

The calculation of potential close to the pipe surface from ground surface measurements using Equation (1) is useful in determining the protective effect without the problem of always positioning the reference electrode close to the pipe surface. Study of Equation (1) indicates that the remote over pipe and close to pipe reference electrode potentials approach one another when:

1. Low protective currents are required (because of resistive coatings or easily polarized cathode surfaces.)
2. The soil resistivity is low.

To find meaning in a pipe to reference electrode potential, the following conditions must be defined:

1. Reference electrode used.
2. Location of reference electrode in relation to the pipeline.
3. Size, depth of burial and position of pipeline in relation to neighboring structures, protective anodes, etc.
4. Soil resistivity.
5. Current applied/lineal foot of pipe.

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Any discussions of this article not published above will appear in the June, 1956 issue.

Internal Casing Corrosion in Sour Oil Wells*

By J. A. CALDWELL and M. L. LYTLE

Introduction

A STUDY of the problem of corrosion of oil well casing shows that there are several mechanisms by which the casing may corrode. In some fields the attack is predominantly external and may be caused by bacterial action, by metallurgical defects in the casing, or by electrolytic action in connection with subsurface electric currents.

Attack on the inside of the casing usually is caused by the action of acid waters standing in the lower part of the tubing-casing annulus. In the case of wells which produce hydrogen sulfide, there also may be severe attack on the casing in the upper part of the well where the space is filled with gas. Apparently, water vapor condenses on the inner wall of the casing, and hydrogen sulfide and carbon dioxide dissolve in the condensed water to form an acid solution which corrodes the steel. In the absence of preventive measures perforation of the casing wall may occur with the result that repairs become necessary.

The costs of repairing casing leaks caused by corrosion may range from a few thousand dollars for a low pressure pumping well to many thousands of dollars for a high pressure flowing well. In the case of a blowout, or even an undetected casing leak in some reservoirs, tremendous quantities of oil may be lost; the actual cost of the failure is difficult to estimate.

The majority of sour oil wells subject to internal casing corrosion fall in the low-pressure category. Many of these wells must be pumped to obtain production. Because of the relatively low productivity of these wells, a low-cost method of reducing internal casing corrosion is needed. One method which appears to be satisfactory is that of setting the tubing on a packer and filling the tubing-casing annulus with oil. Other procedures are to inject a volatile inhibitor such as formaldehyde or ammonia, or large quantities of oil containing an organic corrosion inhibitor. This report describes some preliminary results of both laboratory and field work on oil-inhibitor mixtures, and of laboratory work on paraffin-oil-inhibitor mixtures, in a program designed to determine for such mixtures the cost of injection and effectiveness in reducing internal casing corrosion.

Laboratory Tests and Results

Amount of Material Adhering to Steel Surface

A portion of the laboratory work was directed toward a determination of the amount of oil-inhibitor or paraffin-oil-inhibitor mixture which would adhere to a steel surface. In one test, weighed steel coupons measuring 1-inch x 3-inches x 1/16-inch were immersed for 15 minutes in oil containing a corrosion inhibitor in a concentration of 2.4 percent. The coupons were removed and weighed after the oil-inhibitor coating had been allowed to drain in air for periods of one hour, 1¾ hours, and 72 hours, respectively.

As shown in Table 1, the particular oil used in the test adhered to the steel surface about as well as the same oil containing a corrosion inhibitor. There was some blackening under the oil film containing no inhibitor (an indication of the start of corrosion).

In a second test, coupons of the same type were immersed for 15 minutes at 128-130 F in a different oil-inhibitor mixture to which had been added 10 percent by weight of field paraffin. The coupons were removed and weighed after the paraffin-oil-inhibitor mixture had been allowed to drain for a period of one hour and after a period of 72 hours. Results of tests using the paraffin-oil-inhibitor type of mixture, shown in Table 2, indicated that the presence of a corrosion inhibitor did not cause a greater amount of material to adhere to the steel surface. However, the amount of paraffin-oil-inhibitor mixture adhering to the steel

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Abstract

A low-cost method of reducing internal casing corrosion in sour oil wells is needed. Results of laboratory weight loss tests suggest that treatment of the inside of the casing with an oil-inhibitor mixture may be a feasible solution. Results of other laboratory tests show that the weight of a paraffin-oil-inhibitor mixture adhering to a steel coupon is several times that of the film deposited from an oil-inhibitor mixture alone. Preliminary results of a field test on two wells showed that rapid injection of several barrels of an oil-inhibitor mixture into the tubing-casing annulus gave complete coverage of the outside of the tubing in the gas space and that the film remained intact for at least six months. It is probable that the inside of the casing in the gas space also was completely covered by the oil-inhibitor mixture.

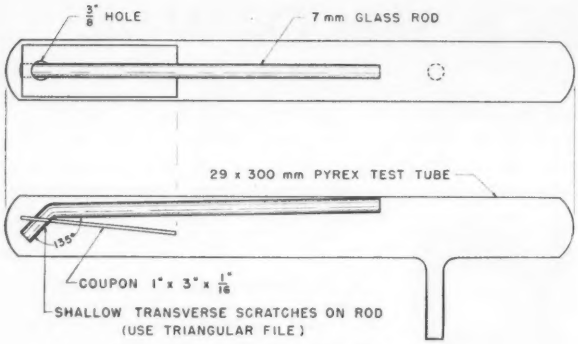
3/8" HOLE
7 mm GLASS ROD
29 x 300 mm PYREX TEST TUBE
135°
COUPON 1" x 3" x 1/16"
SHALLOW TRANSVERSE SCRATCHES ON ROD
(USE TRIANGULAR FILE)

Figure 1—Coupon and holder in test tube.

TABLE 1—Weights of Oil or Oil-Inhibitor Mixtures Adhering to Steel Surface

Inhibitor	Conc. of Inhibitor In Oil[1] Vol. %	Immersion Time for Coupons[2] (Minutes)	WEIGHT IN GRAMS OF FLUID AFTER EXPOSURE TIMES		
			1 Hour	1¾ Hours	72 Hours
None.....	....	15	0.0806 0.0737 0.0772 avg.	0.0448 0.0399 0.0424 avg.	0.0239 0.0237 0.0238 avg.
1[3].....	2.4	15	0.0763 0.0700 0.0737 avg.	0.0420 0.0446 0.0433 avg.	0.0212 0.0248 0.0230 avg.
2[4].....	2.4	15	0.0661 0.0687 0.0674 avg.	0.0471 0.0418 0.0445 avg.	0.0261 0.0263 0.0262 avg.
3[5].....	2.4	15	0.0743 0.0982 0.0863 avg.	0.0510 0.0485 0.0498 avg.	0.0292 0.0314 0.0303 avg.

[1] Oil from Penwell field, Ector County, Texas.
[2] Coupons are of mild steel, 1 inch x 3 inches x 1/16 inch.
[3] Inhibitor is of the high molecular weight amine type. It is oil soluble and water dispersible.
[4] Inhibitor is of the semipolar organic compound type. It is completely soluble in hydrocarbons, relatively insoluble in brine.
[5] Inhibitor is of the high molecular weight nitrogen base compound type.

TABLE 2—Weights of Paraffin-Oil or Paraffin-Oil-Inhibitor Mixtures Adhering to Steel Surface

Inhibitor	Conc. of Inhibitor In Mixture[1]	Conc. of Paraffin In Mixture (Weight %)	Immersion Time for Coupons[2] (Minutes)	WEIGHT IN GRAMS OF MIXTURE AFTER EXPOSURE TIMES	
				1 Hour	72 Hours
None...	....	10	15	0.3066 0.2514 0.2790 avg.	0.2268 0.1827 0.2048 avg.
1[3].....	1.0 vol. %	10	15	0.1562 0.1794 0.1678 avg.	0.1142 0.1288 0.1215 avg.
2[4].....	1.0 vol. %	10	15	0.2608 0.1613 0.2111 avg.	0.1956 0.1108 0.1532 avg.
4[5].....	1.0 vol. %	10	15	0.1610 0.1996 0.1803 avg.	0.1140 0.1374 0.1257 avg.
5[6].....	1.0 wt. %	10	15	0.3197 0.2565 0.2881 avg.	0.2283 0.1751 0.2017 avg.

[1] Paraffin and oil from Bronte field, Coke County, Texas.
[2] Coupons are of mild steel, 1 inch x 3 inches x 1/16 inch; temperature of deposition was 128-130 F.
[3] Inhibitor is of the high molecular weight amine type. It is oil soluble and water dispersible.
[4] Inhibitor is of the semipolar organic compound type. It is completely soluble in hydrocarbons, relatively insoluble in brine.
[5] High molecular weight imidazoline.
[6] High molecular weight aliphatic diamine.

surface was about five times as great as the amount of oil-inhibitor mixture which had been found to adhere to a similar surface in the test described above. This suggests that it may be possible to develop a heavy, low cost coating which will give almost permanent protection to the inside of casing.

Corrosion Rates of Steel Coupons

Another portion of the laboratory work involved a determination of corrosion rates of steel coupons exposed in the vapor phase of systems having some of the characteristics of sour oil well systems. In one test a coupon and a glass device for holding the coupon were placed in a 150 cc capacity test tube equipped with a side arm, and the open end of the tube was sealed in a flame. The complete assembly is shown in Figure 1. The tube was evacuated to the limit of a good water pump, natural gas was injected, and the process of evacuation and filling with gas was repeated four times. The tube finally was evacuated, the desired fluid was drawn in and saturated with hydrogen sulfide, and the side arm was sealed.

The fluid for the various determinations consisted of 50 cc of crude oil, or 50 cc of brine, or 25 cc of crude oil and 25 cc of brine; in all cases a corrosion inhibitor in a concentration of 0.1 percent was added. The 50 cc of fluid in the tube was sufficient to cover the coupon. After an immersion time of one hour the tube was inverted and the coupon exposed in the vapor phase at room temperature. At the end of 90 days the coupon was removed, cleaned, and weighed and the metal loss calculated in inches per year. In each case the inhibitor effected a reduction in corrosion rate of more than 90 percent, as shown in Table 3. The corrosion rate of unprotected coupons (no corrosion inhibitor present) was lowest in tests using oil only. This indicates that brine-free oil should be used for prevention of casing corrosion if no inhibitor is to be used. Results on protected coupons (corrosion inhibitor present) show that an inhibitor should be added to the oil, if possible.

In a second weight-loss test the same type of apparatus was employed, but a 5 percent paraffin-oil mixture containing 1.0 percent inhibitor was introduced into the test tube to cover the coupon. The test tube assembly and fluid had been maintained at 130 F for two hours before the fluid was drawn into the test tube. After an immersion time of fifteen minutes the fluid was drained from the test tube through the side arm. A large hypodermic syringe fitted with a long needle was used for both filling and draining operations. After the paraffin-oil-inhibitor mixture was drained from the tube, the tube was evacuated and flushed with natural gas in the manner described above. Ten to 15 cc of brine was introduced into the evacuated tube, and a 50-50 mixture of carbon dioxide and hydrogen sulfide was added to bring the pressure to atmospheric. The side arm of the tube was sealed and the tube inverted so that the coupon was in the vapor space. The brine was not allowed to touch the coupon at any time.

During an exposure period of 34 days the tube was placed in an oven at approximately 130 F for 1½ hours on each of 13 days, distributed irregularly over the test period. The repeated heating and cooling caused condensation of moisture on the coupon and inside wall of the test tube, simulating to some extent conditions in the annular space above the fluid level in oil wells. Results are shown in Table 4. All of the corrosion rates were low. By comparison with results on control coupons which had not been coated with any material,

a paraffin-oil mixture without inhibitor was found to reduce the corrosion rate by 43 percent; the various paraffin-oil-inhibitor mixtures reduced the corrosion rate by 55 to 80 percent.

Field Test, Sand Hills Field

In June, 1954, a field test was started in an effort to: (1) Determine whether batch treatment down the tubing-casing annulus with oil containing corrosion inhibitor would give complete coverage of the outside of the tubing, and (2) Establish the length of life of the oil-inhibitor film. The interest was primarily in the length of time an oil-inhibitor film would remain on the casing wall. Visual inspection of the inside of the casing was impracticable but it was thought that inspection of the outside of the tubing should give useful information.

Two pumping wells in the Sand Hills field, Crane County, Texas, were selected as test wells. The tubing was pulled and pairs of tubing subs (each two feet long) were installed in the tubing string of each well at depths of 30 feet, 1,500 feet, and 3,000 feet. One sub in each pair was turned in a lathe so as to have mill scale removed; the other sub was merely cleaned with a solvent. After the tubing string had been run back into each well, 15 barrels of lease oil containing 15 gallons of corrosion inhibitor was pumped into the tubing-casing annulus in less than 15 minutes. On the next day the tubing of each well was pulled for inspection of the tubing subs. Other inspections were made on later dates.

Results of Field Test

Results of the various inspections of the tubing strings of the two wells are given in Table 5. A complete oil film was found on the tubing subs in the course of the second inspection for each well. The elapsed time since injection of the oil-inhibitor mixture was then 28 days for Well A and 24 days for Well B. The subs located at 30 feet and 1,500 feet in each well were obviously in the vapor space; the subs at 3,000 feet were below the fluid level.

It is possible that continued drainage from above accounted for the fact that the subs in Well B at 1,500 feet were found to be completely coated on the second inspection, even though they had not been found to be completely coated on the first inspection. On the third inspection, at the end of approximately three months, results were the same as for the second inspection. On the fourth inspection, at the end of approximately six months, the subs in each well at 30 feet and in Well B at 1,500 feet were observed to have a complete oil film, as before. The subs in Well A at 1,500 feet had a heavier oil film than before, and oil was overflowing the tops of the collars.

Discussion of Results of Field Test

It was apparent that the subs at the 30-foot location in each well had the same appearance at the end of six months that they had on the second day after injec-

TABLE 3
Effect of Inhibitor on Corrosion Rates of Pre-Treated Steel Coupons in Vapor Phase

Inhibitor	Conc. of Inhibitor In Liquid (Vol. %)	Composition of Liquid[1]	Immersion Time in Liquid (Hours)	Exposure Time in Vapor (Days)	CORROSION RATE OF COUPONS (in/yr) 1	2	Avg.	Reduction Over Control (%)
4[2]	....	Oil	1	90	0.00072	0.00010	0.00041	....
	0.1	Oil	1	90	0.00003	0.00003	0.00003	93
4[2]	....	Brine	1	90	0.00214	0.00187	0.00201	....
	0.1	Brine	1	90	0.00003	0.00003	0.00003	98
4[2]	....	Oil and brine	1	90	0.00217	0.00145	0.00181	....
	0.1	Oil and brine	1	90	0.00005	0.00007	0.00006	97

[1] Oil and brine from Penwell field, Ector County, Texas.
[2] High molecular weight imidazoline.

TABLE 4—Corrosion Rates of Steel Coupons Coated with Paraffin-Oil or Paraffin-Oil-Inhibitor Mixtures

Inhibitor	Conc. in Inhibitor	Conc. of Paraffin in Mixture (Wt. %)	Coupon Immersion Time in Mixture (Minutes)	Coupon Exposure Time in Vapor (Days)	CORROSION RATE OF COUPONS (in/yr) 1	2	Avg.	Reduction Over Control (%)
None	....	....	[1]	34	0.00033	0.00047	0.00040	....
None	....	5[2]	15	34	0.00022	0.00024	0.00023	43
3[3]	1.0 Vol. %	5	15	34	0.00008	0.00012	0.00010	75
4[4]	1.0 Vol. %	5	15	34	0.00018	0.00017	0.00018	55
5[5]	1.0 Wt. %	5	15	34	0.00008	0.00008	0.00008	80

[1] No coating on coupon.
[2] Paraffin in this and following groups from Bronte field, Coke County, Texas; crude oil from Penwell field, Ector County, Texas.
[3] Inhibitor is of the high molecular weight amine type. It is oil soluble and water dispersible.
[4] Inhibitor is of the semipolar organic compound type. It is completely soluble in hydrocarbons, relatively insoluble in brine.
[5] High molecular weight aliphatic diamine.

TABLE 5—Inspection of Tubing Subs, Sand Hills Field

Well	Inhibitor Injected	Conc. of Inhibitor in Oil (Vol. %)	Date of Injection	Date of Inspection	Remarks
A	1	2.4	6-2-54	6-3-54	All subs had complete oil film. Few drops of water on surface of oil at 30 feet.
				6-30-54	Subs at 30 feet and 1,500 feet had complete oil film. Subs at 3,000 had been standing in oil. Fluid level was at 2,100 feet.
				8-31-54	Same as on 6-30-54. Fluid level at 2,500 feet.
				11-30-54	Subs at 30 feet had complete oil film. Subs at 1,500 feet had heavier oil film; oil was overflowing tops of collars. Oil level appeared to be just above 1,500 feet. Subs at 3,000 feet had been standing in oil; both were bright when recovered, but the lathe-turned sub darkened rapidly.
B	2	2.4	6-8-54	6-9-54	Complete oil coverage at 30 feet. Incomplete at 1,500 feet. Standing in oil at 3,000 feet.
				7-2-54	Complete oil coverage at 30 feet and 1,500 feet. Standing in oil at 3,000 feet. Fluid level at 2,000 feet.
				9-2-54	Same as on 7-2-54. Fluid level at 2,200 feet.
				12-2-54	Subs at 30 feet wet with oil; very much like subs from other well at corresponding location. Subs at 1,500 feet wet with oil. Subs at 3,000 feet had been standing in oil. Fluid level at 1,950 feet.

tion of the oil-inhibitor mixture. The manner in which the subs at 1,500 feet in Well A became heavily coated with oil has not been determined. Some of the possibilities are the existence of a tubing leak, a bubble of gas which pushed oil upward, or foaming.

Cost of Injection of Oil-Inhibitor Mixture

During 1954, the semi-annual injection of an oil-inhibitor mixture for prevention of internal casing corrosion was started into some 200 Humble wells in West Texas. The average cost of treatment per well was about $25. Included in this figure are the cost of corrosion inhibitor, labor, and use of pump truck.

Conclusions

1. The corrosion rate of mild steel exposed under conditions similar to those existing in the tubing-casing annulus of a sour oil well is substantially reduced by the presence of a suitable oil-inhibitor film.
2. The addition of field paraffin to an oil-inhibitor mixture permits the deposition of a relatively thick protective coating on a steel surface.
3. The rapid injection of copious quantities of a suitable oil-inhibitor mixture into the tubing-casing annulus of a sour oil well gives complete coverage of the outside of the tubing in the gas space. The film will remain intact for at least six months; because of this it may be feasible to use the above mentioned process for protecting the inside wall of the casing.

DISCUSSION

Question by John D. Sudbury, Continental Oil Company, Ponca City, Oklahoma:

What were the results of examination of tubing surfaces other than the specially machined subs discussed in the paper?

Reply by J. A. Caldwell:

Each string of tubing was installed several years prior to start of the test. No special surface preparation of the tubing was made. The tubing appeared to have a good coating of oil on the outside six months after injection of the oil-inhibitor mixture.

Any discussions of this article not published above will appear in the June, 1956 issue.

DISCUSSIONS ON TECHNICAL ARTICLES ARE SOLICITED

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Effect of Water on Strength of Structural Plastics*

By W. H. SHARP and M. K. WEBER

Introduction

IT IS OF PRIME importance to have information on the behavior of a structural material as a function of time under load in environments of intended use. There has been sufficient experience in a multitude of applications with old materials such as metals, concrete, or brick to predict their behavior quite well while stressed under most conditions. Such wide experience and understanding is yet to be obtained, however, for the reinforced plastics being developed for structural applications.

The oil and gas production industry affords one of the most important large scale markets for glass fiber reinforced plastic tubular goods. These materials are made attractive to the engineer both by the light weight of the materials and by the possible elimination of corrosion problems. In the above service, however, they would be subject to many types of loading forces such as tension, burst, and collapse. In addition the materials would have to be resistant to crude oil, gas, and salt water over a range of temperatures.

Creep tests under constant load have been made on filled thermosetting resins.[1,2,3] These tests were made in air only and gave no information as to the effects other environments might have on long term strength of plastic materials. Studies have been made of mechanical properties of reinforced plastics at low and high temperatures in air.[4,5] Considerable effort also has been expended in improvement of the wet strength of glass fiber reinforced plastics,[6,7,8] but none of the test methods for this work used constant stress on the specimen during exposure to water. Because so little was known about performance of this material under constant load in oil or water, long term laboratory tests were initiated to obtain data that would be helpful in design and in indicating service life.

Results of First Tests

The tubing used in the first tests was constructed of roving and polyester resin. A fixed deformation type of tension test was selected because it provided one type of stress the tubing would be required to carry. A second reason this test was used was that the equipment needed was rather simple. In the tests the applied stress was 50 percent of the ultimate short term dry strength. Creep was measured with bonded SR-4 strain gages on the tubing, and stress was maintained by increasing deformation as creep occurred. The tests were made in duplicate in air, salt water, and crude oil.

After 14 days in air at 150 F when creep had become almost negligible, two samples were immersed in crude oil and two in oil field brine. The air test was terminated after three months and the oil test after ten months. In neither case did the tubes show signs of failure and creep was minor.

It was found, however, that 2.5 hours after the tubes were placed in brine the loads dropped off one half and could not be raised by increasing the deformation. Sixteen hours later the load could not be raised to one-tenth that carried in air. It was found that the tubes had been elongated sufficiently to cause necking down.

This quick failure in simple water solution while the tube was stressed to only 50 percent of its dry tensile strength was unexpected. In a standard method for evaluating laminates, mechanical tests are made on the wet specimens immediately after removal from water in which they have been immersed for specified periods of time. This type of test shows the

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Abstract

Evidence is presented to show that glass reinforced plastics undergo substantial reductions in strength when exposed to water. Emphasis is placed on the importance of determining the total loss of strength by creep measurements in the environment and at the temperature of interest. Results from such measurements are much more revealing than the commonly used method of short term immersion followed by rapid ultimate strength measurements in air. Convenient methods are described for obtaining comparative creep strength data for resins, for flat laminates and for pipe sections. Results obtained from these methods are used to indicate the most important factors which determine the wet strength of resin and of glass reinforced resin.

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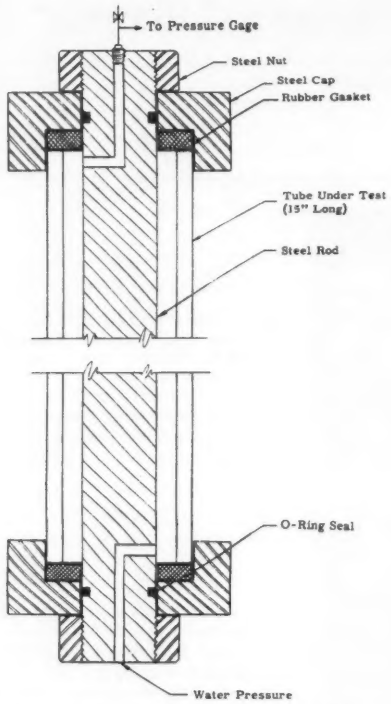

Figure 1—Apparatus for hydraulic burst tests. The device is placed in a constant temperature oven.

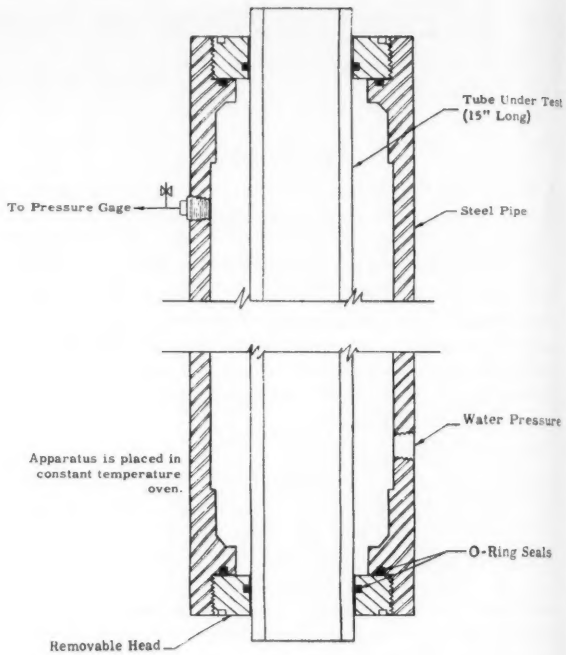

Figure 2—Apparatus for hydraulic collapse tests.

strength retention of polyester laminates to be good when glass fibers are coated with a 114 type chrome complex finish such as used on the roving in these tubes.

Supplementary tests were made on glass fiber mat reinforced polyester tube samples in which constant internal or external water pressure was applied at different temperatures (110 F and 150 F). The apparatus is shown in Figures 1 and 2, and results are summarized in Table 1. Although no direct comparison tests were made in air, the results from the tensile tests described and other experiments being made at the time indicated that the weakening was caused by water. The pressure test results at the two temperatures clearly showed that the deterioration was far more rapid at the higher temperature.

Selection of Laboratory Test Methods

The failures described pointed to a need for study of the factors which affect the strength of glass fiber reinforced plastics. Of interest were the effects of environmental factors (primarily water and temperature) and also the effects of fabrication variables such as different resins, their curing agents, curing cycles, and glass fiber finishes. The failure in tension and results of the pressure and collapse tests indicated the need for tests under constant load in environments similar to those of the proposed exposure. Flat laminates were selected for this study because the preparation of samples was more convenient and the fabrication variables would be under better control.

Tests were made on samples from three different polyester laminates in order to determine which of the most common mechanical tests (flexure, tension, or compression) would be best suited for the study. The specimens were immersed in tap water at 150 F. In all tests the constant load applied was 50 percent of the ultimate failure load of the same size specimen

TABLE 1—Constant Pressure Tests of a Polyester Resin-Glass Fiber Mat Tube

Test Pressure[1], psig	Hoop Stress, psi	TIME TO FAILURE, DAYS	
		110 F	150 F
600[2]	3600	0.4 (rupture)	<0.1 (rupture)
400[2]	2400	16 (leaking)	.....
300[2]	1800	60 (weeping)	0.3 (rupture)
200[2]	1200	.....	6 (leaking)
500[3]	....	0.4[4]	.....
400[3]	....	.....	0.2
200[3]	....	27	0.5
100[3]	....	.....	4.1

[1] Rapid Strengths Data

TYPE	Temperature, Degrees F.	psig at Rupture
Burst	75	1000
Burst	150	1500
Collapse	75	1500
Collapse	150	800

[2] Internal pressure.
[3] External pressure.
[4] All external pressure test failures were by rupture.

TABLE 2—Time to Failure of Glass Fabric-Resin Laminates Under Different Types of Constant Load

SAMPLE	TIME TO FAILURE, MINUTES		
	Flexure	Compression	Tension
2C	81	25	450
2E	25	7	105
OJ	0.2	<1	7

in air at 75 F. In flexure the specimen supported the load at the center of a two-inch span; in compression the load was applied to the ends of the specimen which had a thickness to height ratio of one to four. The tensile tests were made on dumbbell type specimens with a two-inch gage length.

As shown in Table 2 all specimens failed rapidly. The interesting observation is that all specimens showed the same relative order of time to failure. Therefore, the flexural test method was selected because of its convenience.

Constant Load Flexure Test Method

Constant load flexure tests were made with the appartus shown in Figure 3. With this simple fixture, deflection-time and time to failure data can be obtained for flat strip specimens under simple beam loading midway between two supports. A wide range of constant flexural loads can be applied conveniently while the specimen is under environment and temperature conditions of interest. Flexural strength measurements were made on samples as received at 75 F in air, and the results were calculated by the formula in the ASTM Method "Flexural Test of Plastics" (D790-49T). Initial stress calculations for specimens under constant load tests were made using the same formula.

Deflection-time data obtained in this manner are dependent on many fabrication variables such as glass finish, type of resin, cure of resin, and reproducibility of cured resin characteristics (assuming a given orientation of glass is used.) These measurements thus provide a simple means of comparing effects of variables which produce relatively large changes in flexural strength.

Table 3 gives data obtained from flexural deflection-time measurements which illustrate the effect of water on flat glass cloth reinforced laminates. Although these data show that water appreciably affects the strength of both polyester and epoxy laminates, the latter show marked superiority in water resistance. It is of interest to note that the flexural strength of the epoxy sample which had been exposed to oil was unchanged when it was tested in air at 75 F. Flexural deflection-time curves for the epoxy samples are shown in Figure 4.

Ring Crush Test

The effect of water on glass reinforced plastic pipes is shown readily by a variation of flexural loading which may be called the ring crush test. In this test measurements are made of the deflection of a tubing ring under a diametrical compressive load. Ring crush strength can be measured by loading a ring in a standard testing machine until failure occurs and the load decreases.

More informative constant load tests can be made with a modification of the constant load flexure test fixture. By replacing the loading tip blade with a flat disc and removing the lower supports, this fixture can be used to obtain deflection-time data which indicate the effect of environment. Admittedly the stress pattern is complex, and the data on tubes of different sizes and constructions cannot be correlated. In addition to this the data cannot be used for design purposes. Ring crush measurements are quite useful, however, for obtaining relative data for the effect of environment on a given tube or for determining the effect of different resins and cures on tubes of similar construction. Ring crush strengths were measured in air at 75 F; rings for both types of tests were one-half inch wide.

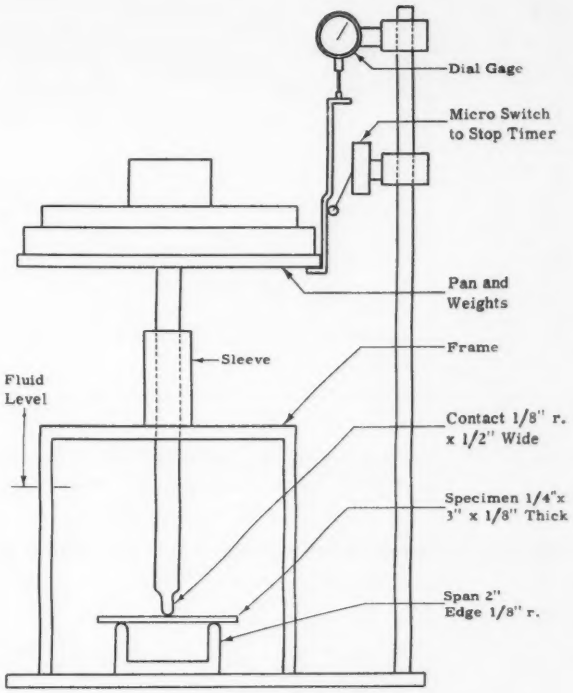

Figure 3—Apparatus for constant load flexure tests.

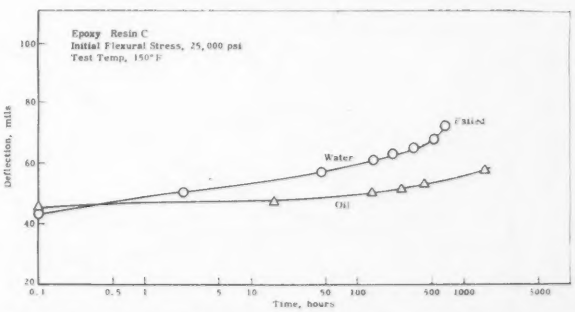

Figure 4—Flexural deflection-time curves for flat laminate under constant load.

TABLE 3—Time to Failure of Flat Laminates Under Constant Flexural Load in Air, Water and Oil

Resin in Laminate	Flexural Strength in Air at 75 F, psi	Initial Flexural Stress, psi	TIME TO FAILURE AT 150 F, Hour		
			Air	Water	Oil[3]
Polyester A...	51,300	25,700	>245[1]	1.9	.....
Polyester B...	46,400	23,200	74	0.2	.....
Epoxy C.....	79,000	39,500	....	54	.....
Epoxy C.....	79,000	25,000	....	685	>1600[2]

[1] Creep rate practically zero after 215 hours. Test terminated.
[2] Test terminated. Flexural strength in air at 75 F unchanged.
[3] Heavy white oil.

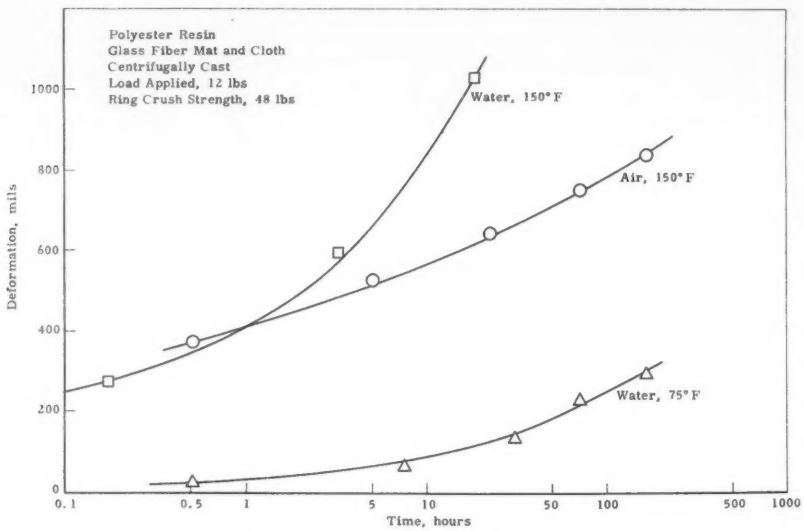

Figure 5—Deformation-time curves for tube samples under constant ring crush load (load applied, 12 pounds).

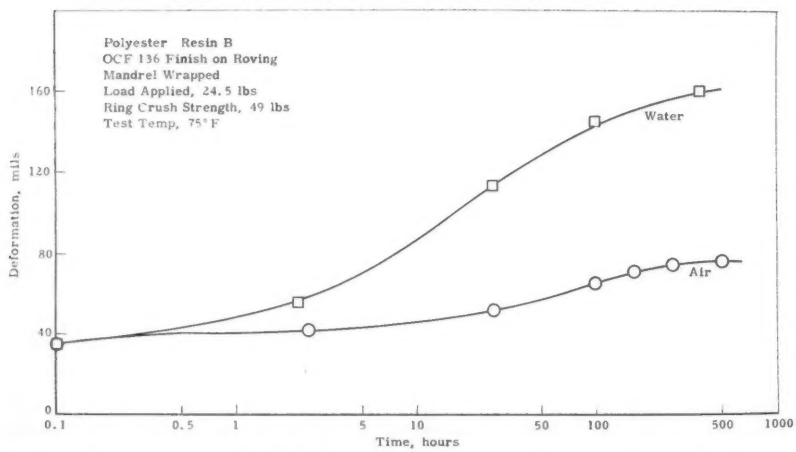

Figure 6—Deformation-time curves for tube samples under constant ring crush load (load applied, 24.5 pounds).

TABLE 4—Effect of Presoaking in Water on Ring Crush Strength of Glass Reinforced Epoxy Resin Pipes

Pipe No.	Wall Thickness, Mils	Time of Presoak, Days	Weight Gain, Percent	Type of Glass	TIME, HOURS	
					To 200 Mils Deflection	To Failure
4[1]	111	0.003	....	150-114	83	93
4[1]	111	1	0.11	150-114	(56)[2]	> 51 <115
4[1]	111	6	0.35	150-114	18	50
4[1]	111	30	0.83	150-114	<0.02	<0.02
12	114	0.003	....	140-120 PX	(0.1)[2]	1.5
12	114	1	0.54	140-120 PX	0.01	0.02
12	114	6	1.5	140-120 PX	....	[3]
12	114	30	2.5	140-120 PX	....	[4]
14	135	0.003	....	ECG-140, 7.3-L-1	(66)[2]	74
14	135	1	0.14	ECG-140, 7.3-L-1	47	54
14	135	6	0.33	ECG-140, 7.3-L-1	<5	5
14	135	30	0.79	ECG-140, 7.3-L-1	<0.02	<0.002

Load applied, 70 pounds; exposure and deflection measurements in 150 F water.

[1] Ring crush strength 196 pounds.
[2] Estimated values where data were insufficient to define curve accurately.
[3] Failure time was 1 hour under 40 pounds load.
[4] Failure time was less than one minute under 40 pound load.

Examples of the effects of water in constant load ring crush tests of various types of tubing rings are given in Figures 5 to 8. Figure 5 shows that a glass mat and cloth reinforced centrifugally cast polyester resin pipe had an appreciable creep rate in water at 75 F at only 25 percent of the ultimate strength of the tube in air. At 150 F the same tube deformed much more rapidly in water than in air under the same load. Figures 6 and 7 show significantly greater deformation rates for a mandrel wrapped polyester resin tube reinforced with glass roving when in water than when in air at the same temperature. Figure 8 contains curves on which temperature sensitivity is shown for ring crush measurements on a mandrel wrapped epoxy tube. In all cases the rate of deformation of tubes was significantly greater in water than in air.

A useful variation of the ring crush test was employed with epoxy resin tubes which had such high ring crush strengths that comparable constant load data in water and air were difficult to obtain. The effect of water on these high strength mandrel wound tubes was demonstrated clearly by constant load ring crush measurements in hot water on samples which previously had been immersed without load in the water for different lengths of time. Time to failure decreased from as high as 93 hours on rings loaded five minutes after immersion in 150 F water to practically zero time for rings presoaked one month. Examples of these measurements are given in more detail in Table 4.

Factors Affecting Wet Strength of Reinforced Plastics Resin

Many factors affect the wet strengths of resins to a significant degree. The following brief treatment is not intended to cover all cases, but rather to emphasize three of the factors which have been found to exert a large influence on wet strength. These three factors are type of resin, curing agent, and curing cycle.

The effect of water on resins can be shown by measurements of the flexural strength of strips of unreinforced (cast) resins by methods that were used for the reinforced resins. The amount of water absorbed as a function of time is shown in Figure 9. The effect of the amount of water absorbed on the flexural strength is shown in Figure 10. Severe weakening of the resin was found to occurr very rapidly during the initial period of rapid water absorption. The weakening effect of water on Polyester Resin A also is indicated by flexural deflection-time measurements under constant load. After a few hours under load the creep rate for the strip in water increased sharply over that of the strip in air under otherwise identical conditions. Similar measurements on cast Polyester Resin B showed even greater differences between wet and dry strengths. Figure 11 shows flexural deflection-time curves for both resins in air and water.

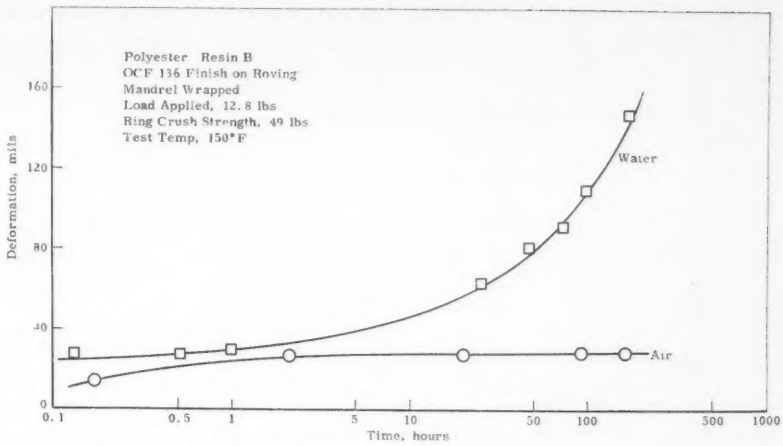

Figure 7—Deformation-time curves for tube samples under constant ring crush load (load applied, 12.8 pounds).

Extension of these measurements to other types of resins indicates load carrying abilities also are affected to varying degrees by the presence of water. Constant load flexural deflection measurements on unreinforced strips of one of the most water resistant epoxy resins indicate that even this resin is appreciably weakened by water although the effect is not so rapid nor so great as for other resins tested (see Figure 12).

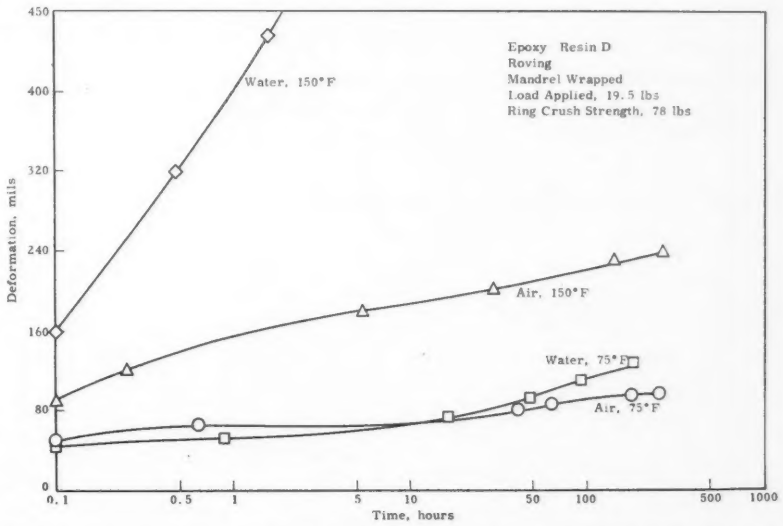

Figure 8—Deformation-time curves for tube samples under constant ring crush load (load applied, 19.5 pounds).

In comparing this resin's behavior with that of Polyester Resin A, it is interesting to note the dependence of results on method of testing. Immersion in water at 150 F for a month produced no significant loss in flexural strength in air at room temperature for the epoxy resin (see Table 5) as contrasted with nearly 50 percent reduction for the polyester resin.

That water also had adversely affected the epoxy resin was indicated by both constant load and flexural strength measurements on specimens immersed in hot water (Table 6 and Figure 12). Both types of measurements under these more severe conditions showed clearly that water reduced the strength. These results emphasize the importance of testing plastic materials under conditions as similar as possible to conditions of use.

The deterioration caused by water is not limited to thermosetting resins of the polyester and epoxy types. An indication of the reduction in strength of thermoplastic resins is given by comparative flexural deflection-time data for three widely used

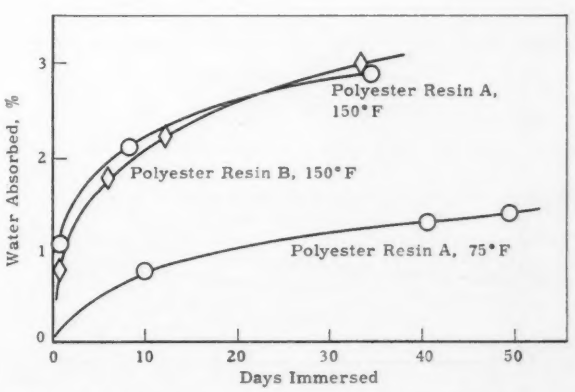

Figure 9—Water absorbed by cast resins as a function of time.

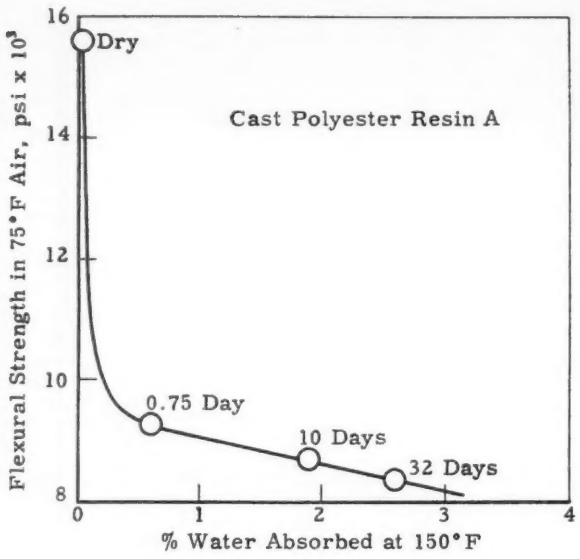

Figure 10—Strength as a function of water absorption.

TABLE 5—Effect of Water on Flexural Strength of Three Epoxy C Resin Panels

Panel No.	FLEXURAL STRENGTH		Change, Percent
	Original[1], psi	After Exposure[2], psi	
1a	21,400	20,400	—5
2a	21,000	20,100	—4
3a	20,100	19,800	—1

Exposure: No load, 150 F, 1 month.
Test Environment after Exposure: Air at 75 F.
[1] Average of 5 samples. Maximum deviation among any group of five: 11.2 percent.
[2] Average of 2 samples. Maximum difference in any pair: 13.1 percent.

TABLE 6—Effect of Water on Flexural Strength of Epoxy Resin Cast Panel 2a at 150 F

CONDITIONS		Flexural Strength After Exposure, psi	Change in Flexural Strength (Basis 150 F, Air
Exposure (No Load)	Test Environment After Exposure		
4 days, air	Air	18,700[1]	0
1 day, air	Water	16,600	—11
1 hour, water	Water	15,900	—15
5 days, water	Water	14,400	—23
5 mo., water	Water	12,900[2]	—31

[1] Flexural strength in air at 75 F was 21,000 psi.
[2] Single measurement on this panel. Result is similar to those obtained from two other panels of similar resin. All other results are average of five test results. Maximum deviation among any group of five: 15.1 percent.

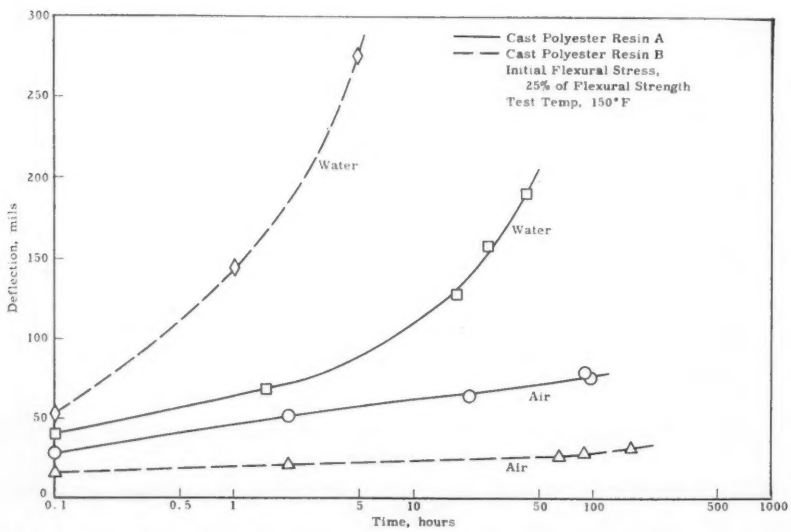

Figure 11—Flexural deflection-time curves for cast resins under constant load (cast polyester resins A and B.)

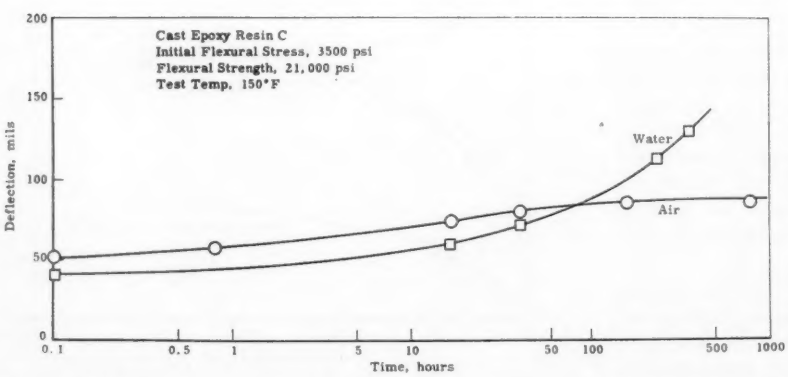

Figure 12—Flexural deflection-time curves for cast resin under constant load (cast epoxy Resin C).

thermoplastic resins (Table 7). In water at 110 F under flexural loads ranging from 15 to 25 percent of their flexural strength in air at 75 F, strips of unplasticized polyvinyl chloride, styrene copolymer, and cellulose acetate butyrate deflected 1.7 to 9.6 times as much in water as in air under otherwise identical conditions.

In addition to the behavior changes caused by water on resins of different composition, large differences in wet strength of some resins can be obtained by different curing agents. An example of the striking differences obtainable from Epoxy C flat laminates by using different curing agents for otherwise similar systems is illustrated by the variations in time to failure of four flat laminates under constant flexural load in water at 150 F (Table 8).

Considerable improvement in wet strength can be produced by changes in resin curing cycle. An example of such a change was shown in flexural deflection-time measurements on two samples from the same cast Epoxy C panel. The panel had been cured at 212 F for two hours and then part of it was post cured for one hour at 400 F. After 50 hours under the same constant load in water at 150 F, the sample which had not been post cured showed a deflection of 290 mils whereas the other sample

showed only 77 mils. It should be noted, however, that to date the most favorable resin type cured under optimum conditions still is appreciably weakened by exposure to water while under load.

Glass

Glass generally is considered to be a stable, inert material unlikely to contribute to the weakness of glass reinforced plastics in water. Considerable evidence exists, however, to contradict the popular conception that the mechanical properties of glass are unaffected by common environments. Measurements by Baker and Preston[9,10] showed Pyrex glass rods to be two and a half times as strong in very high vacuum as when in contact with water vapor at atmospheric pressure. The reduction in strength was found to be very rapid; only ten seconds exposure to water vapor were required to halve the strength of the rods as measured in vacuum.

It is also of interest to note that the long term strength of glass was found to be considerably less than the strength as measured in short term tests. This continued fatigue or decrease of strength of glass under constant load appears to result primarily from the continued attack of water. Experiments by Anderegg[11] have confirmed the observations of Baker and Preston to show that the strength of glass as fibers is reduced by the presence of water.

Laminates made by applying resins directly to glass have been found to have poor wet strength. This undesirable behavior, to the extent that is not accounted for by effects of water on resin, can be attributed both to deterioration of the glass-resin bond in water and to weakening of the glass.

In order to minimize the effect of water on reinforced plastics, many types of glass finishes or coupling agents have been developed. These finishes are applied to the surface as very thin films. They are designed to provide active groups on each end of the molecule which will bond to the glass and to the resin to provide a more water resistant bond than can be obtained by applying the resin directly to glass. Most of this work has been directed toward providing improved finishes for use with polyester resins. Reports on the relative wet strength of polyester resin laminates made with various glass finishes indicate that considerable improvement has resulted.[6,7,8]

Little information has been published on the effectiveness of finishes for use with other types of resins. Limited experience in the authors' laboratory indicates no one commercial finish to be outstanding for use with different epoxy resins. Comparative data obtained from flexural tests of flat laminates in water at 150 F indicated one finish to be significantly better than two others with a particular resin. However, for another epoxy resin no significant difference was observed (Table 9).

Experimental chlorosilane glass finishes have been described recently which are said to give good results with epoxy and phenolic as well as polyester resins.[12] Further study is needed on application of a suitable coupling agent to the fresh glass immediately after it is drawn into fiber. One advantage of this method of surface treatment would be the obtaining of a clean, reactive surface at the outset. The alternative to this is attempting to apply a coupling agent to glass which has been exposed to water vapor and which has been treated with sizing lubricants as is current manufacturing practice.

Discussion

The results obtained in this study emphasize the deteriorating effect of water on plastic materials. Measurements have shown that the strengths of all polyester or epoxy glass reinforced plastics examined are reduced appreciably by exposure to water. This weakening appears to result from deterioration of the resin, the glass, and the glass-resin bond. The manner in which water effects these changes is not yet understood, but because resins of many widely different chemical compositions are affected, it appears probable that the change in the resin is of a physical nature with the water acting as a plasticizer or internal lubricant for the movement of the large resin molecules.

Results of rapid burst tests at room temperature have little value because the combined effects of heat, water, and constant load can cause pipes to fail within days or even hours at a small fraction of their

TABLE 7—Effect of Water on Flexural Deflections of Thermoplastic Resins at 110 F

MATERIAL[1]	Initial Stress in Percent of Flexural Strength	Duration, Hour	Deflection[2], Mils		Ratio of Deflection, Water/Air
			Air	Water	
Cellulose acetate-butyrate	18	21	53	510	9.6
Styrene copolymer	15	1870	33	76	2.3
Styrene copolymer	25	1870	44	189	4.3
Unplasticized polyvinyl chloride	25	1560	55	102	1.9
Unplasticized polyvinyl chloride	32	1560	75	127	1.7

[1] Specimens cut from extruded pipe, ca. 0.12 x 0.5 x 2.5 inches.
[2] Deflections listed are those at termination of test minus the deflection immediately after application of load.

TABLE 8—Time to Failure of Epoxy C Laminates Prepared With Different Curing Agents

Sample No.	Curing Agent	Flexural Strength in Air at 75 F, psi	Initial Flexural Stress, psi	Time to Failure in Water at 150 F, Minutes
10J	X	72,000	36,000	<1
31D	X	70,000	35,000	<1
68J	Y	80,000	40,000	90
82	Z	80,000	40,000	3240

TABLE 9—Effect of Glass Finish on Flexural Strength of Laminates Under Constant Load[1] in 150 F Water

RESIN	Type Glass Finish	Time to Failure, Hours
Epoxy D	Chrome	15
Epoxy D	Silane	16
Epoxy D	Improved chrome	15
Epoxy C	Chrome	50
Epoxy C	Silane	198
Epoxy C	Improved chrome	461

[1] Load sufficient to give 25,000 psi initial flexural stress.

burst strength at room temperature. No quick simple method is available for accurately assessing the hydraulic load a glass fiber reinforced pipe will sustain owing to the large number of interrelated factors involved.

To obtain service life information the material must be tested under environment and load conditions approaching as close as possible those of actual practice. To obtain an estimate of the effect of environment or temperature on a material, or on materials combined in a given manner, the constant load flexure test and ring crush tests (for panels and tubes, respectively) have been found to be useful. It is believed these tests would be useful also to the manufacturer who wishes to observe the effect of such fabrication variables as resin composition and cure or glass finish on wet strength.

Acknowledgment

The authors acknowledge the cooperation of their colleagues in Shell Chemical Corporation and Shell Development Company. Special thanks is extended to Aaron Wachter.

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Any discussions of this article not published above will appear in the June, 1956 issue.

The Determination of the Effect of A New Grass Killer on Application Equipment*

By J. A. KELLY, W. J. FALKENSTEIN and J. P. CARR

Introduction

DALAPON SODIUM SALT, technical, is a white, free-flowing powder which is readily soluble in water. It is made by neutralizing 2,2-dichloropropionic acid with sodium hydroxide as shown below:

$$CH_3-CCl_2-C(=O)-OH + NaOH \rightarrow$$

$$CH_3-CCl_2-C(=O)-ONa + HOH$$

(Dalapon sodium salt)

The sodium salt is soluble in water to the extent of 57 grams per 100 grams at 20 C. It may be considered insoluble in oils. The dry solid is quite hygroscopic and will pick up sufficient water from a humid atmosphere (90 percent relative humidity) to dissolve itself. Because of this fact a moisture proof container is required for shipping and storage purposes. In this respect the chemical resembles sodium trichloroacetate.

Under certain conditions, Dalapon sodium salt will hydrolyze in aqueous solutions. The probable hydrolysis reaction is as shown below:

$$CH_3-CCl_2-C(=O)-ONa \xrightarrow{\text{Heat}} + H_2O \rightarrow$$

$$CH_3-C(=O)-C(=O)-OH + NaCl + HCl$$

(pyruvic acid)

Application Equipment

Early in the development program, laboratory investigations were undertaken to determine whether or not a corrosion problem existed with spray strength solutions of Dalapon sodium salt when used in conjunction with metals commonly found in spray equipment.

The equipment used to apply the solutions includes the standard types of high pressure sprayers, low pressure sprayers (less than 150 psi), and specialized sprayers such as are used for railroad bed work. The materials of construction of such sprayers include copper, brass (yellow), phosphor bronze, cold rolled steel, cast iron, stainless steel (18-8), galvanized steel, and aluminum.[2]

For the purpose of preliminary laboratory testing, steel, yellow brass, aluminum, and galvanized iron

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J. P. CARR is employed by John Bean Division, Food Machinery and Chemical Corp., Lansing, Mich., where he is concerned with the development of agricutural sprayers and specialized farm equipment. Mr. Carr was graduated from Purdue University in 1935; since that time he has been active in the field of research and development of mechanical equipment. His experience includes a World War II tour of duty in the Army Ordnance Department.

Abstract

Laboratory tests have been conducted to determine the possible corrosive effect of aqueous solutions of Dalapon sodium salt (sodium 2,2-dichloropropionate), a new grass killer, on the metals present in typical agricultural field sprayers. From preliminary study, it was concluded that solutions of the chemical could be used in agricultural field sprayers of standard construction with little effect on the materials of construction. In order to corroborate these findings, a standard production model agricultural field sprayer was obtained from the John Bean Division, Food Machinery and Chemical Corporation, for test purposes. The sprayer was operated for a period of four weeks using standard concentrations of Dalapon sodium salt in water and observations were made. From these data and from observation of the disassembled sprayer after testing, it is concluded that the chemical exhibited slight but not significant effect on the materials of construction.

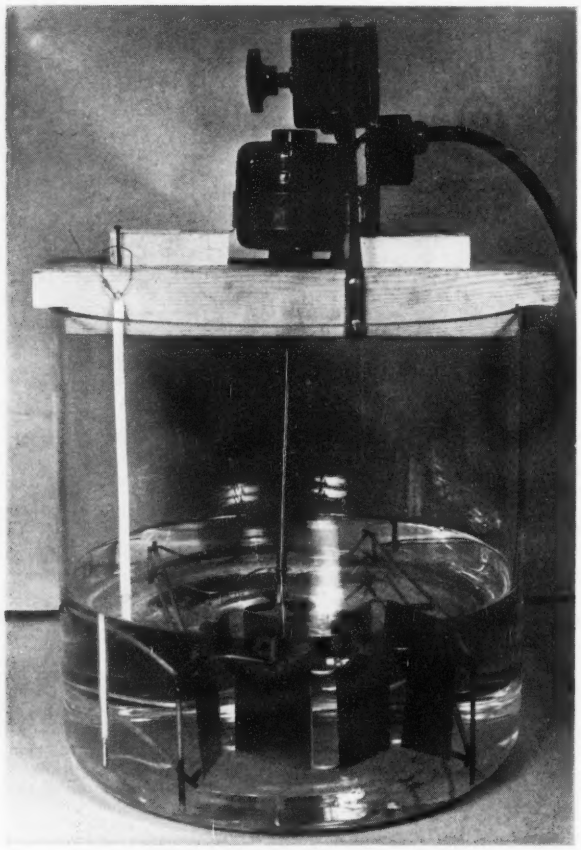

Figure 1—Laboratory corrosion test unit.

were chosen as metals representative of usual sprayer construction and corrosion tests were run.

Laboratory Corrosion Test Device

The test used simulated the situation found in a sprayer by providing for the following factors:[3]

1. The time of exposure of test specimens to a given lot of solution was comparable to field practice. Corrosion data often is reported that was obtained in static tests where a metal specimen was exposed to a given agricultural chemical solution for extended periods. Under such conditions, breakdown of the chemical with resultant formation of corrosive by-products could occur far beyond that experienced in normal use of the chemical.

2. Agitation was provided. Static tests often fail to provide the conditions of aeration present in a spray tank and thus do not expose the chemical to conditions as rigorous as in actual practice. Also, corrosion inhibitors on occasion may show good protection in a static test, but fail to give protection under conditions of sprayer tank agitation. Without agitation of the test solution, this fact may be overlooked.

3. The common metals of sprayer construction were included in the test. This was desirable in order to observe any unusual effects from the presence of dissimilar metals in the actual sprayer.

Figure 1 shows the simple laboratory corrosion test unit used in the experiments which embodies the factors previously discussed. A round five gallon battery jar fitted with a center-located, three-bladed propeller-type stainless steel agitator is the heart of the unit. In practice, the agitator is driven at a constant speed (approximately 600 rpm—this can be varied if certain situations call for more or less vigorous agitation). The specimen rack, made from stainless steel rod, is designed to hold four metal specimens 1-inch x 1½-inch. These specimens may be all of the same metal or may be of dissimilar metals. The temperature of the test may be controlled by the addition of a regulator (not shown).

The unit described is useful in laboratory evaluation of the corrosiveness of agricultural chemicals as the test is rapid and only small amounts of materials are needed.[3]

Test Results

Most of the laboratory corrosion testing was done using the unit described above. Preliminary tests were run, however, using a static test in which a water solution containing four pounds of Dalapon sodium salt per gallon was placed in six ounce glass bottles; cold rolled steel strips ½-inch x 3 inches were added and the bottles were stoppered. The solutions were kept at 75-80 F for 28 days and the pH remained constant at 4.5 during the test. The corrosion rate in ipy[1] was .00174. In addition, under the conditions of this test, slight pitting was noted.

In a similar test of 14 days duration at 120 F an ipy of .155 was obtained with severe pitting. In the latter test, the pH dropped from an initial reading of 4.5 to 2.0. Inorganic chloride analysis showed 60.2 percent of the Dalapon sodium salt had decomposed. From these data, it became apparent that marketing of concentrated aqueous solutions of Dalapon sodium salt in steel drums was out of the question inasmuch as temperatures of 120 F are commonly experienced in transit. For this reason the product is sold as a dry powder except for special shipments in insulated tank cars.

Tests were run with spray strength solutions containing ½ pound of Dalapon sodium salt per gallon in the apparatus previously described. The data given in Table 1 illustrate that Dalapon sodium salt solutions at spray strength affect galvanized iron by removing the zinc. With zinc present, the steel is, of course, protected while the zinc lasts. With steel alone in the system the rate rises to .0945 ipy.

Upon reviewing the work thus far described, one questions how well the laboratory data correlates with field experience. To learn this, various operators who used Dalapon sodium salt were queried regarding their corrosion experience with the material. Nothing much was gained in this effort, however, as all reports were negative (that is to say, no corrosion was noticed by the operators involved). This led to the idea of obtaining a new sprayer of typical standard manufacture for the purpose of determining under service conditions the effect of the chemical on the materials of construction.

[1] Ipy (Inches penetration per year) = 365 × weight loss in grams ÷ number of days of test × area in square inches × $(2.54)^3$ × density.

Sprayer Testing

A. Equipment Used

On a mutual cooperation basis, the John Bean Division of the Food Machinery and Chemical Corporation, supplied a new model 44-T, 50 gallon power sprayer for test purposes. The sprayer chosen was representative of a size frequently used in applying Dalapon sodium salt solutions and was typical of standard manufacture in all respects.

The sprayer consisted of a 50 gallon steel tank fitted with a steel agitator mounted on a trailer. A single cylinder gasoline engine operated the agitator and the high pressure plunger-type pump. The steel tank had been Bonderized, the exterior painted and the interior coated with a vinyl-type plastic lining material. The agitator shaft was not coated. The portions of the pump exposed to solution included the cast iron valve chamber and the miscellaneous parts made of brass, stainless steel, steel, plastic and porcelain. The piping was made of ordinary steel or synthetic rubber hose.

Galvanized iron was not present in this sprayer. The total area of steel exposed to solution has been calculated by the sprayer manufacturer to be approximately 340 square inches.

B. Test Procedure

In order to arrive at a meaningful test procedure to be used with the sprayer, discussions were held with individuals expert in the field use of the chemical in sprayers of this type. Thus it was possible to establish fairly well such factors as concentration of salt to be used, length of exposure, equipment cleaning practices commonly used on farms, likely operating temperatures, and length of storage of the equipment between use periods. On the basis of this information, the test procedure described below was decided upon. Operations were carried on in the laboratory building (see Figure 2 for a general view of the arrangement).

The three methods referred to in the previous paragraph are the following:

Method No. 1

1. Before starting run, have mechanics remove cylinder head and valve chamber from the pump. Remove from left cylinder the outlet valve and spring, stainless valve cage, porcelain cylinder, brass plunger hold-down bolt, steel plunger washer and composition plunger. Wash all parts thoroughly to remove grease. Dry metal parts with acetone; dry porcelain and composition parts with a cloth. Weigh each part and record weights on data sheet. Photograph removed pump parts.
2. Have pump reassembled and sprayer hooked up with spray boom and nozzles. Photograph exterior and interior of sprayer.
3. Fill tank half full with Midland City water, start agitator and add 25 pounds Dalapon sodium salt. Add remainder of water (to 50 gallons total) and agitate for five minutes. Take an eight ounce sample from tank drain. Record temperature of solution in tank.
4. Spray out entire contents of tank to the sewer. Take eight ounce sample at end of run from tank drain. Record temperature of solution, then drain tank completely.
5. Fill tank half full with Midland City water, run unit five minutes while spraying. Stop unit and drain tank as completely as possible. Let stand idle one full day.

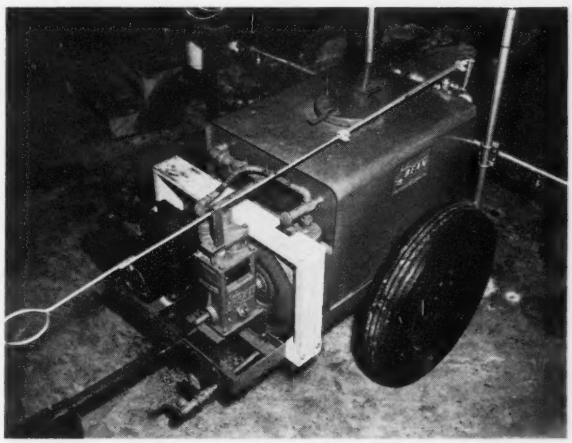

Figure 2—Power sprayer used in tests.

TABLE 1—Corrosion by Dalapon Sodium Salt Solutions at ½ Pound Per Gallon in Laboratory Test (Agitated, No Inhibitor) Two Hours Exposure

Test Number	Specimen Metal(s)	Temperature (Degrees F)	pH	Corrosion Rate (ipy)
1	Steel (alone)	75	5.3	.0945
2	* Steel	79	4.9	.00514
	* Galvanized iron			.528
	* Aluminum			.0099
	* Brass			.0016
3	* Steel	80	4.9	.1065
	* Aluminum			.0079
	* Brass			.0016

* Metals listed in each test are all present electrically connected. Corrosion rates given are for the individual metals in this situation.

Method No. 2

1. Fill sprayer as directed in Method No. 1. Take eight ounce sample from tank drain. Record temperature of solution.
2. Spray one-fourth of the contents of the sprayer. Shut off unit and let stand one hour.
3. Spray remainder of solution.
4. Take eight ounce sample from tank drain at end of run. Take temperature of solution.
5. Rinse sprayer as directed in Method No. 1—5.

Method No. 3

1. Fill sprayer as directed in Method No. 1. Take eight ounce sample from tank drain. Record temperature of solution in tank.
2. Spray one-fourth of the contents of the sprayer. Shut off unit and let stand four hours.
3. Spray remainder of solution.
4. Take eight ounce sample from tank drain at end of run. Record temperature of solution.
5. Rinse sprayer as directed in Method No. 1—5.

Method No. 4

1. Fill sprayer tank as directed in Method No. 1. Take eight ounce sample from tank drain. Record temperature of solution in tank.
2. Spray one-fourth of the contents of the sprayer tank. Shut off unit and let stand over night.
3. Spray remainder of solution.
4. Take eight ounce sample from tank drain at end of run. Record temperature of solution.
5. Rinse sprayer as directed in Method No. 1—5.

The above schedule was repeated three times for a total of twelve runs. A thirteenth run similar to Method No. 4 also was included using Midland City water as a type of check run in order to determine

how much iron was supplied by the water alone. Analysis showed this to be nil.

On reviewing the test procedure, it can be seen that allowance was made for a considerable variety of situations such as might logically be encountered by a farmer in the course of using this weed killer on his farm. For example, allowing the sprayer to stand over night three-fourths full represents the kind of thing that happens when a farmer's activity might be interrupted by adverse weather. Except in unusual situations, Dalapon sodium salt would not be used continuously by a farmer. For this reason alternate periods of use were thought to be necessary in order to evaluate the effect of trace amounts of the chemical not removed by the rinsing procedure.

TABLE 2—Summary of Iron Analyses on Spray Solutions From Test Runs With John Bean Sprayer

Sample Number	Time of Sampling During Run	Minutes Solution In Tank	pH	Analyses (Total Solids Basis)	
				Fe (±.005) Gms/50 Gals	Fe Increase Gms/50 Gals During Run
1-A	Start	5	5.1	0.5155	0.5475
1-B	End	50	5.1	1.0630	
5-A	Start	5	4.75	0.3785	.....
5-B	End	36	4.75	0.1892	
9-A	Start	5	4.6	0.2878	0.4237
9-B	End	45	4.6	0.7115	
				Average[1]	0.4855
2-A	Start	6	5.0	0.6750	.....
2-B	End	103	5.0	0.4540	
6-A	Start	5	4.75	0.2584	0.0916
6-B	End	100	4.75	0.3500	
10-A	Start	5	4.60	0.4070	0.8650
10-B	End	115	4.60	1.2720	
				Average[2]	0.4783
3-A	Start	5	5.0	0.4650	0.2370
3-B	End	279	5.0	0.7020	
7-A	Start	5	4.6	0.4165	0.6055
7-B	End	282	4.6	1.0220	
11-A	Start	5	4.6	0.5300	0.7290
11-B	End	283	4.6	1.2590	
				Average[3]	0.5238
4-A	Start	5	4.8	0.0852	1.4466
4-B	End	1392	4.7	1.5318	
8-A	Start	5	4.6	0.4165	1.7615
8-B	End	1490	4.5	2.1780	
12-A	Start	5	4.8	0.4430	1.9320
12-B	End	1399	4.8	2.375	
				Average[4]	1.7134

[1] The above six tabulations were all for Test Method No. 1.
[2] The above six tabulations were all for Test Method No. 2.
[3] The above six tabulations were all for Test Method No. 3.
[4] The above six tabulations were all for Test Method No. 4.

TABLE 3—Tabulation of Weight Loss or Gain for Pump Parts

Pump Part No.	Identification of Pump Part	Type of Metal or Material	Weight of Pump Parts In Grams			Remarks
			At Start of Test	At End of Test	Loss or Gain in Weight	
1219610	Valve Cage	Stainless Steel	12.040	12.040	None	
1222355	Disc and Spring Assembly:	.....	11.833	11.8288	—.0042	A spot of solder (50 percent Pb—50 percent Sn) was on the disc and may account for the weight loss.
	Disc Part	Chrome Steel	8.0630	8.0588	—.0042	
	Spring Part	Stainless Steel	3.770	3.770	None	
1216829	1¼ inch ID Cylinder Type AB-2	Ceramic Porcelain	137.4290	137.5663	...1373	
1219800	Cup Washer	Low Alloy Steel	9.9170	9.8350	—.0820	
1112014	Brass Cap Screw 5/8 inch—18 x 5/8 inch	Brass (Muntz Metal)	13.6440	13.6431	—.0009	
1216827	1¼ inch Plunger Packing	Plastic	5.3800	5.3700	—.0100	

C. Test Data from Sprayer Runs

Samples of solution taken at the beginning and end of each test were analyzed for pH and percent iron. The iron analyses are given in Table 2.

A corrosion rate for the 340 square inches of exposed steel in the sprayer was calculated using the total amount of iron found, analytically, in the solutions. It was found that 13.108 grams of iron were removed. The exposure time was 3.88 days. The corrosion rate of steel in this test was calculated to be .0282 ipy.

In addition to the chemical analyses given above, data were obtained regarding weight loss or gain for several of the small parts removed from the sprayer pump. These data are summarized in Table 3. There was little effect noted on these metals either in weight lost or in change in appearance upon examination.

D. Examination of Sprayer After Testing

Inspection of individual components by the sprayer manufacturer's laboratory personnel revealed only the typical appearance normally expected to be seen in sprayers exposed to other generally used agricultural chemicals under comparable conditions. No chemical effect on the stainless steel, brass or coated steel parts was noted. No indication of swelling or other deterioration of the synthetic rubber hoses or pump plunger packings was found. Exposed steel and cast iron parts were moderately affected as evidenced by a light rusting of the surfaces.

Discussion

Field experience with Dalapon sodium salt solutions, the operating test with the power sprayer

TABLE 4—Comparison of Corrosion Rates of Uninhibited Sodium TCA Solution (50 Percent) With Dalapon Sodium Salt Solution (6 Percent)

METAL	Corrosion Rate (Mils per Year)	
	50 Percent Sodium TCA (Static, 21 Days) (Alquist-Wasco)*	6 Percent Dalapon Sodium Salt, 2 Hours (Agitated)**
3S Aluminum	Disintegrated	9.9
Mild Steel	3.58	94.5–(28.2)
Yellow Brass (70-30)	27.6	1.6
Galvanized Iron	White Precipitate	528

*At Room Temperature.
**At 75-80 F.

TABLE 5—Comparison of Corrosion Rates (mpy) for Dalapon Sodium Salt Solution With Sodium TCA Solution Versus Various Metals

METAL		Corrosion Rates (Mils per Year)	
		Sodium TCA, 0.5 Pound/Gallon Commercial Sample—Inhibited	Dalapon Sodium Salt, 0.5 Pound/Gallon
Mild Steel (alone)		11	93
Galvanized Iron (alone)		143	612
Aluminum (3S) (alone)		48	12
Yellow Brass (alone)		1	1
Mild Steel	Same Test	3	5.1
Galvanized Iron		332	528
Aluminum (3S)		68	9.9
Yellow Brass		1	1.6

and laboratory corrosion testing have all contributed to the knowledge of the effect this chemical has on equipment. To further develop this picture, it is well to look at another similar agricultural chemical that has been used for several years and see how Dalapon sodium salt compares with it. Sodium trichloroacetate is such a chemical. It is in the same chemical family as Dalapon sodium salt and is both a water soluble salt and a grass killer.

It is not possible to find exact comparisons with the two chemicals as the data available were obtained from different tests. However, data by Alquist and Wasco[4] regarding corrosion rates for uninhibited sodium TCA solution shed some light on the comparison if the differences in test methods and concentration are kept in mind (see Table 4).

In the comparison made in Table 4, it is seen that Dalapon sodium salt solutions show a greater effect on iron than do sodium TCA solutions. The effect on aluminum appears considerably improved, however. It is important to note this fact as aluminum spray booms and guns are commonly used.

In regard to galvanized iron, the white precipitate reported in the static test for sodium TCA indicates formation of reaction products of the zinc which in the agitated test with Dalapon sodium salt were carried away. Thus, on the basis of this comparison, Dalapon sodium salt solution appears to be similar to sodium TCA in regard to its corrosive effect on metals of sprayer construction.

Obviously, the comparison just made was open to much question so laboratory tests were run using the equipment previously described and with sodium TCA and Dalapon solutions of the same concentration. Test conditions were kept constant as regards temperature, vigor of agitation and exposure time. In these tests, each of the test metals were run separately and in combination. Conditions of the test called for a temperature of 75-80 F. The sodium TCA used was a regular inhibited sales item; the Dalapon sodium salt used was an uninhibited regular sales item. Concentration was ½ pound salt per gallon with a two hour exposure. Other data are given in Table 5.

From the data in the lower half of Table 5 where corrosion rates are given for the metals, electrically connected as in a sprayer, one would expect the two chemicals to affect application equipment to about the same degree. In this connection it is interesting to note that the authors have yet to learn of a sprayer damaged by sodium TCA solutions. Because the action of the two materials is similar, it seems reasonable to expect that the Dalapon sodium salt solution will not cause any greater practical problem.

Conclusions

Dalapon sodium salt has been found to have a corrosion rate of .0282 ipy for mild steel when tested in an agricultural field sprayer. Laboratory corrosion tests designed to simulate the corrosion situation in a sprayer gave rates higher than this—rates being approximately three times as high for steel (.094 ipy).

On the basis of critical examination of the sprayer after the test, it is concluded that Dalapon sodium salt can be used in ordinary spray equipment in typical use with little effect on the materials of construction. The small scale laboratory tests have proven useful in that a more complete picture was obtained of corrosion possibilities inherent in the chemical. This was done at an early date in the development program so that label recommendations could be written recommending proper use and cleaning practices for the new chemical as it was being introduced.

Comparison of Dalapon sodium salt corrosion rates with rates obtained for sodium TCA, a grass killer with considerable use history, indicate the two chemicals to be similar in action on materials of construction.

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The Conductometric Method Applied to the High Temperature Oxidation of Iron*

By GEORGE C. FRYBURG*

Abstract

The conductometric method is used to study the oxidation of pure iron in the region of 600 C. Iron ribbons of known thickness were used in the tests and the conductance of the central portion of the specimens measured by the potentiometer method. A constant current of 50 ma, small enough to prevent heating even in vacuum, was used. It was found that the conductivity method gives a true measure of the thickness of iron oxidized and yields results that are in agreement with those obtained by the gravimetric method.

An analytical method of measuring the amount of unoxidized iron remaining in specimens is described briefly.

Introduction

THE CONDUCTOMETRIC METHOD of following the oxidation of a metal was first used by Pilling and Bedworth[1] to study the oxidation of calcium. Palmer[2] and Dravnieks[3] have applied the method to copper. The use of this method is possible because of the fact that the conductivity of oxides is negligible compared to that of metals. As a result of this the decrease in conductivity of a metal wire or ribbon undergoing oxidation can be used to measure the rate of oxidation.

The conductometric method has the following advantages:

1. The technique of measurement is simple and lends itself to automatic recording.
2. The progress of the oxidation can be observed continuously.
3. The entire oxidation curve can be obtained with one specimen.
4. The method gives a direct measure of the amount of metal consumed. Because of this the oxidation rates of metals can be compared directly without detailed knowledge of the composition of the oxide phase.

Recently in this laboratory there was a need for a quick, simple method of surveying the rates of oxidation of iron in different oxidizing environments in the temperature region of 600 C. The conductometric method seemed best suited to this purpose; this paper describes the experiments performed in dry oxygen to test the validity of the results.

Theoretical Approaches

One of the oxides of iron, magnetite, has a high conductivity compared to most oxides.[4] At elevated temperatures this conductivity amounts to several percent of that of iron. Hence, in applying the conductometric method to iron, one might expect the results to be in error, especially after considerable oxidation has taken place with the oxide phase constituting a large fraction of the wire. The simple analysis described below was developed to determine what this error might be.

Consider first a metal whose oxide has negligible conductivity compared to the metal. If the metal is in the form of a ribbon whose width is large compared to the thickness, the thickness of metal at any time during the course of an oxidation is directly proportional to the conductance. The thickness of metal oxidized (on each side) is given by the following equation:

$$\tau = \frac{t_0}{2}(1 - \kappa/\kappa_0), \tag{1}$$

where t_0 is the original thickness of the metal, and κ_0 and κ are the original conductance and the conductance at the given time, respectively.

If the conductivity of the oxide is not negligible compared to the metal, κ is the sum of the conductances of the oxide and the metal phases, and τ calculated from the measured conductance is in error. To determine the error at different stages in the oxidation, let 1/n be the fraction of t_0 remaining as iron at any given time. Then the thickness of the iron and oxide phases, respectively, are:

$$t_{Fe} = t_0/n \tag{2}$$

$$t_{oxide} = \varphi(1 - 1/n)t_0 \tag{3}$$

where φ is the familiar volume ratio of the oxide to the metal from which it is formed. Expressing κ and κ_0 in terms of the appropriate thickness and conductivities, and substituting into Equation (1), one obtains:

$$\tau = \frac{t_0}{2}\left(1 - \frac{1}{n}\right) - \frac{t_0\varphi}{2}\left(1 - \frac{1}{n}\right)\frac{\sigma_{oxide}}{\sigma_{Fe}} \tag{4}$$

where the σ's are the specific conductivities.

When the conductivity of the oxide is negligible compared to the metal, τ is equal to the first term of Equation (4). When the conductivity of the oxide is not negligible, the value of τ calculated from the conductance is too small by the amount given by the second term of Equation (4). Hence, the fractional error in τ is given by:

$$-\varphi\frac{\sigma_{oxide}}{\sigma_{Fe}} \tag{5}$$

Equation (5) indicates the important fact that the fractional error in τ is independent of the amount of oxidation, depending only on the volume ratio, φ,

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and the ratio of the conductivities. Hence, in a parabolic plot of τ against the square root of the time, the shape of the curve is not altered by the oxide conductivity. If the oxidation follows the parabolic law, the correct rate constant can be obtained simply by increasing the observed rate constant by the fraction given by Equation (5).

In the case of iron the oxide phase consists of three oxides and only the magnetite contributes to the conductance. To determine the error to be expected in conductivity data, it is necessary to know what fraction of the oxide phase is magnetite. The composition of iron oxide scales has been carefully studied by Davies, Simnad and Birchenall[5] and by Paidassi.[6] Paidassi also has shown that the relative fractions of the different oxides remain constant during oxidation at constant temperature. Using these data and conductivity data for iron and magnetite, and taking $\varphi = 2$, the percentage error has been calculated for different temperatures (see Table 1). The results indicate that the error due to magnetite conductivity is negligible except in the region 500 to 600 C. Below 500 C the conductivity of the magnetite is too low to cause significant error. Above 600 C the fraction of magnetite in the oxide is so small that its high conductivity is offset. The error is greatest at 570 C but even there it is only as large as the experimental error generally encountered in oxidation studies.

The important point brought out by this development is that the fractional error in conductivity data is constant during oxidation so that the shape of the parabolic plot is not altered.

Experimental Approaches

The conductometric method is valid if only the formation of oxide changes the conductivity. The solution of a gas in a metal may alter the conductivity if the solubility is large enough. Dünwald and Wagner[7] have shown that the solubility of oxygen in iron between 800 and 1000 C is less than 0.01 percent. No effect of oxygen solubility on conductivity could be discerned in the present work. Also, recrystallization of iron is thought to affect the conductivity. In these experiments the conductivity was stabilized by heat treatment.

High purity iron (99.99 percent) obtained from A. D. Mackay, Inc. was used. It was rolled into strips approximately 0.001 to 0.002 inch thick. Small ribbons 1.5 inches long and 0.060 inch wide were cut with a die from the strips; the thickness was obtained accurately from the area, weight, and density. The ribbons were split back ¼ inch on each end, and current and potential leads of iron thermocouple wire were spot welded to them. A constantan wire also was spot welded to one of the ends to measure the temperature of the specimen. The wires were brought out through ceramic insulators within a long quartz tube, and waxed to make a vacuum tight seal. The quartz tube was mounted in an O-ring slip seal so that the iron specimen could be moved within the furnace tube without affecting the vacuum. The furnace tube was a large quartz tube, long enough so that the specimen could be withdrawn from the furnace. Suitable pumping equipment and gas supplies were attached.

The conductance of the central portion of the specimens was measured by the potentiometer method. A constant current (50 ma), small enough to prevent heating even in vacuum, was used.

The conductometric method calls for a high constancy of temperature during oxidation. This was obtained by means of a Putmo proportional controller, set so that the off-on-off cycle was about 40 seconds. The regulating thermocouple was heavy gauge chromel-alumel and was placed close to the winding of the furnace.

The procedure followed during an oxidation was as follows: The as-rolled specimen was degreased in acetone, then heated in dry hydrogen at 875 C for 10 hours to anneal and to recrystallize. Equilibrium was established at the reaction temperature. Then the hydrogen was pumped out (to less than 1 micron) and argon (purified over calcium at 425 C) was admitted. The argon was pumped out to 50 mm mercury and the oxidation started by admitting dry oxygen to a pressure of 700 mm mercury. The conductance of the specimen remained constant from the time equilibrium was established until the oxygen was admitted.

Results and Discussion

In several of the runs the conductance of the specimen was measured at room temperature just before and after the oxidation. Since the conductivity of magnetite can be neglected at room temperature, this offered a means of checking the results obtained at elevated temperature. The comparison is shown in Table 2. The final values of τ obtained from the high

TABLE 1—Percent Error in Iron Conductivity Data Due to Conductivity of Magnetite

Temperature Degrees C	Conductivity[a] of Iron, $ohm^{-1}cm^{-1}$	Conductivity[b] of Magnetite, $ohm^{-1}cm^{-1}$	Percent Magnetite in Scale	Percent Error
25	10×10^4	69	100	0.15
500	2	270	100[c]	2.7
550	1.6	320	100[c]	4.0
570	1.5	330	100[c]	4.5
600	1.4	350	50[c]	2.5
625	1.3	360	25[c]	1.4
700	1.1	380	5[d]	0.2
800	0.94	395	4[d]	0.3
900	0.87	410	4[d]	0.35

[a] Values obtained from Metals Handbook, page 425 (1948).
[b] Values obtained from graph of reference 4.
[c] Values obtained from reference 5.
[d] Values obtained from reference 6.

TABLE 2—Comparison of Results Obtained by Different Methods

Specimen Number	t_0, μ	Oxidation Temperature, Degrees C	Final τ Calculated From Reaction Temperature Data, μ	Final τ Corrected For Oxide Conductivity, μ	Final τ Calculated From Room Temperature Data, μ	Final τ Calculated by Other Methods, μ
1	67.5	550	1.34	1.39	1.4	1.45[a]
2	53.0	600	10.92	11.2	11.5	11.5[a]
3	58.9	600	3.65	3.75	3.85	3.8[a]
7	58.0	550	17.6	18.3	....	18.1[b]
8	49.7	605	21.1	21.6	21.8	22.2[b]

[a] Oxide layer flaked off.
[b] Analytical method.

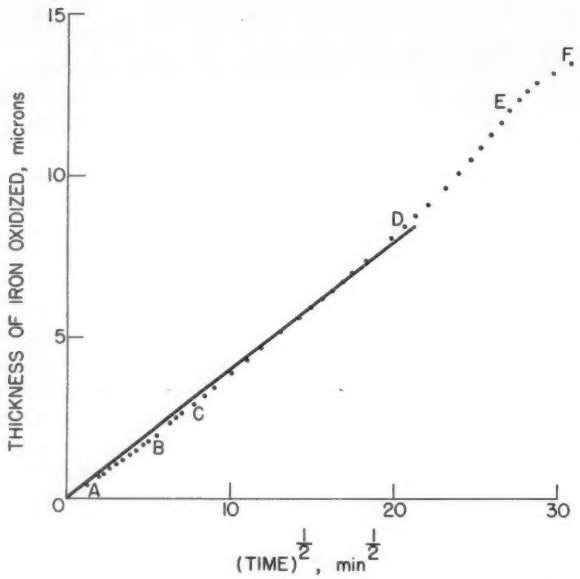

Figure 1—Typical results of oxidation of iron specimen at 600 C in 700 mm mercury of dry oxygen, $t_o = 28.7\mu$.

TABLE 3—Parabolic Rate Constants of Iron Oxidized in 700 mm Mercury of Dry Oxygen

Specimen Number	t_0, μ	Temperature, Degrees C	RATE CONSTANTS, μ/Min$^{1/2}$ Region CD of Figure 1	Average for First 400 Min.	Calculated From Data of Reference 4
4	28.7	605	0.43	0.41	0.43
5	28.1	605	0.46	0.44	0.43
6	59.0	605	0.58	0.48	0.43
7	58.0	550	0.18	....	0.17

temperature data are given in column 4; they were corrected by the method described above. The corrected values are given in column 5 and may be compared to the values obtained from the room temperature data given in column 6. It is seen that the correlation is good.

In some cases it was possible to check the conductivity results by other methods. For specimens in which the oxidation had not been carried too far, it was possible to flake off the oxide layer by gentle bending of the ribbon. The dimensions and weight of the iron strip remaining were measured and the thickness calculated. For specimens from which the oxide could not be easily removed, an analytical method[1] was used to obtain the weight of unreacted iron remaining in the specimen. With this and the area, the thickness was calculated. The values of t_0 obtained by these methods are given in column 7. They compare well with the conductivity results.

A typical oxidation curve, obtained from conductivity data, is shown in Figure 1. This is a parabolic plot of the thickness of iron oxidized against the square root of the time. The oxidation follows the parabolic law initially until about 2.5μ of iron have been oxidized (region AB). Then the oxidation proceeds faster than parabolic for a while (region BC), then passes into region CD where the parabolic law again is obeyed (but with a somewhat larger rate). When about 85 percent of the iron has been oxidized the rate begins to drop off due to the lack of iron (region EF).

In the thinner ribbons ($t_0 = 25\mu$) there is a region between 65 and 85 percent of iron oxidized (region DE) in which the rate increases and follows a linear law. This probably is due to cracking of the oxide film caused by the strain set up in the specimen by the formation of the oxide scale (the ribbons were noticeably curved at this stage). Dunnington, Beck, and Fontana[8] have observed a mechanism of scale formation on iron pertinent to this behavior.

The values obtained for the parabolic rate constants corresponding to the region CD in Figure 1 are presented in column 4 of Table 3. These listings have been corrected for magnetite conductivity. In column 5 are given the average rate constants for the first 400 minutes obtained by drawing the best line through the points. Such a line is shown in Figure 1 and the points lie as close to the line as in the case when a gravimetric technique is used.

The rate constants of Davies, Simnad, and Birchenall[5] have been converted to units of microns of iron oxidized per minute$^{1/2}$ using the oxide scale compositions given by them; namely, 50 percent Fe_3O_4 and 50 percent FeO at 600 C, and 100 percent Fe_3O_4 at 550 C. These converted values are given in column 6 and agree favorably with the author's rate constants.

In conclusion it may be stated that the conductivity method can give a true measure of the thickness of iron oxidized and yields results that are in agreement with those obtained by the gravimetric method.

[1] In this analytical method specimens were pulverized in a saturated solution of copper sulfate and left on a magnetic stirrer for about 48 hours. Metallic iron went into solution, displacing copper ions; oxides were unaffected. The solution was made acidic with acetic acid, and the oxide, and displaced copper filtered off. Filtrate was made basic with excess NH_3 precipitating the iron as the hydroxide. Hydroxide was filtered off and dissolved in 1:1 HCl. The iron was reprecipitated to remove traces of copper and redissolved. The final solution was analyzed for iron colorimetrically by the mercaptan acetate (thioglycolate) method. The author is indebted to Dumas Otterson for help in developing this procedure.

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Any discussions of this article not published above will appear in the June, 1956 issue.

The Mass Transfer Properties of Various Metals and Alloys in Liquid Lead*

By J. V. CATHCART and W. D. MANLY

Introduction

THE PHYSICAL PROPERTIES of liquid metals give these materials unique advantages in many technological applications. Their high heat capacities, excellent thermal conductivities, and generally low viscosities make them ideal as heat transfer media. Because of their relatively low vapor pressures it is possible to use these materials at much higher temperatures than more conventional coolants such as steam, thus increasing markedly the efficiency of heat transfer. The mercury boiler, sodium-cooled valves (used in aircraft engines) and sodium-potassium and lead heat-treating baths are a few examples of current applications of liquid metals to industrial processes.

Despite the advantages mentioned above, the use of liquid metals has been limited in many cases by technical difficulties associated with the corrosive properties of the materials. In recent years, however, the demand for compact, high level power sources has created a renewed interest in high-temperature heat-transfer agents, and attention again has been focused on liquid metals.

The phenomenon of mass transfer has been the most serious obstacle to the use of liquid metals as high temperature coolants. The term "mass transfer" is used here to indicate the solution of material from the hotter regions of a container and its transport by the flowing liquid metal to the cold zone of the system where the excess dissolved material is precipitated. Very frequently this material is deposited in the form of fine dendritic crystals. Thus, in a boiler or heat exchanger the pipes in the cooler regions soon become completely clogged by masses of interlocking crystallites.

The research which is described in this paper represents a study of mass transfer suffered by a series of metals and alloys in liquid lead. No special effort was made to find an alloy which was highly resistant to mass transfer in liquid lead. Rather, the aim of the research was the comparison of the mass transfer properties of the common pure metal alloying agents with corrosion resistance of the alloys themselves. In this manner it was hoped that at least an empirical basis could be established for estimating the resistance to mass transfer of a given alloy.

Laboratory Tests

Tests were made in small thermal convection loops constructed of ½-inch diameter quartz tubing (see Figure 1). Six-inch tubes of the test metals were inserted in the hot and cold legs of the loops. The time required for the deposition in the cold leg of enough mass transfer material to halt the flow of the lead was used as the basis for the comparison of the relative resistance to mass transfer of the test materials. The details of the construction and operation of a typical loop already have been reported.[1]

The hot-leg temperature for all the loops operated was 800 C. The cold-leg temperature was about 500 C, thus producing a temperature gradient of 300 C across the system. The flow rate of the liquid lead in the loops was not measured, although it was estimated to be on the order of 1 ft/min. This rate of flow is, of course, much smaller than that which would be required in a full scale system.

In all, 24 metals and alloys were studied. The results are summarized in Figure 2. All tests were

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Abstract

The relative resistance to mass transfer in liquid lead of 24 metals and alloys were measured. Tests were performed in small quartz thermal convection loops. The test temperature was about 800 C with a thermal gradient of 300 C existing across the loops. Of the metals and alloys studied, only columbium and molybdenum exhibited a high resistance to mass transfer. Nickel and nickel-rich alloys were highly susceptible to mass transfer. Evidence is presented to show that alloys in which a tendency toward intermetallic compound formation exists show a higher resistance to mass transfer in liquid lead than do their pure metal components.

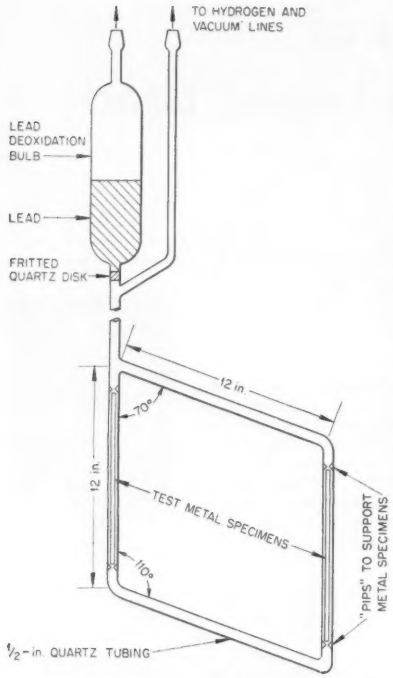

Figure 1—Quartz thermal convection loop.

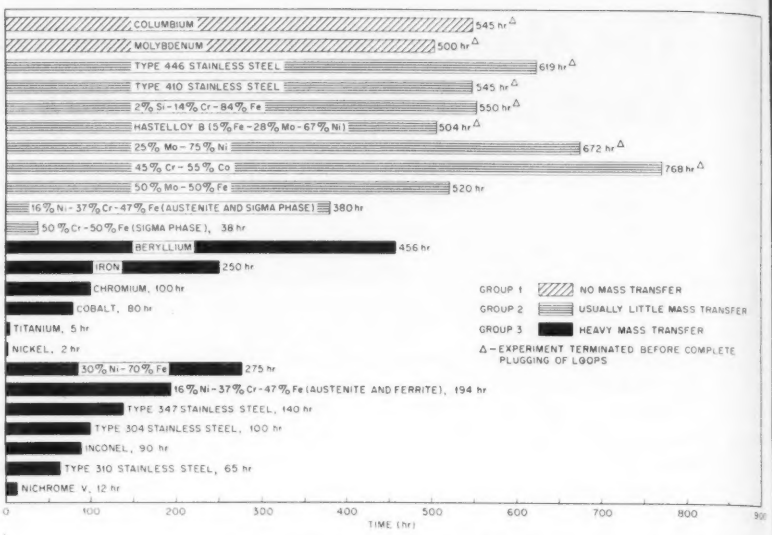
COLUMBIUM 545 hr△
MOLYBDENUM 500 hr△
TYPE 446 STAINLESS STEEL 619 hr△
TYPE 410 STAINLESS STEEL 545 hr△
2% Si-14% Cr-84% Fe 550 hr△
HASTELLOY B (5% Fe-28% Mo-67% Ni) 504 hr△
25% Mo-75% Ni 672 hr△
45% Cr-55% Co 768 hr△
50% Mo-50% Fe 520 hr
16% Ni-37% Cr-47% Fe (AUSTENITE AND SIGMA PHASE) 380 hr
50% Cr-50% Fe (SIGMA PHASE), 38 hr
BERYLLIUM 456 hr
IRON 250 hr
CHROMIUM, 100 hr
COBALT, 80 hr
TITANIUM, 5 hr
NICKEL, 2 hr
50% Ni-70% Fe 275 hr
16% Ni-37% Cr-47% Fe (AUSTENITE AND FERRITE), 194 hr
TYPE 347 STAINLESS STEEL, 140 hr
TYPE 304 STAINLESS STEEL, 100 hr
INCONEL, 90 hr
TYPE 310 STAINLESS STEEL, 65 hr
NICHROME V, 12 hr
GROUP 1 NO MASS TRANSFER
GROUP 2 USUALLY LITTLE MASS TRANSFER
GROUP 3 HEAVY MASS TRANSFER
△—EXPERIMENT TERMINATED BEFORE COMPLETE PLUGGING OF LOOPS
0 100 200 300 400 500 600 700 800
TIME (hr)

Figure 2—Mass transfer in liquid lead.

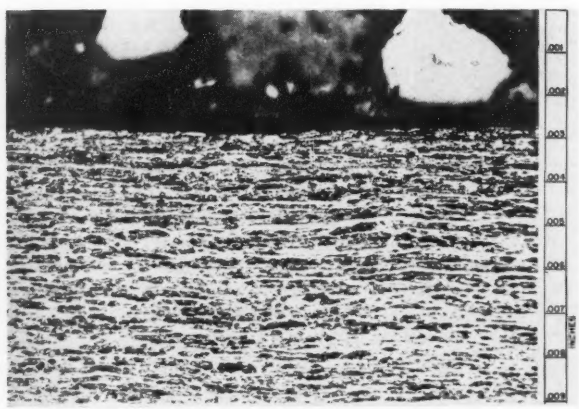

Figure 3—Transverse section of hot-leg specimen from lead-molybdenum loop. 255X.

made in duplicate except those with titanium, beryllium, 30 percent nickel-iron, 45 percent chromium-55 percent cobalt, and Nichrome V. Only one test was performed with each of these latter metals and alloys.

The number at the end of each bar in Figure 2 represents the average length of time the loop in question was operated. For the duplicate runs variations in plugging times of about 10-15 percent were observed. Complete plugging occurred in all loops except those indicated by "△." In these latter cases the tests were halted intentionally after the times specified. Even though complete plugging did not occur, small amounts of mass transferred material were found in all these loops with the exception of those containing molybdenum and columbium. It was estimated that all loops exhibiting only relatively small amounts of mass transfer after 500 hours would eventually have plugged completely.

Very little is known concerning the factors which control the rate of mass transfer, and it would be dangerous to assume the data reported herein are also valid in systems having both a large temperature gradient and a high flow rate. It is believed, however, that the data will be useful in selecting for further testing materials that are most likely to prove satisfactory under actual operating conditions.

The mass transferred material taken from the loops was analyzed chemically. With a few notable exceptions there was comparatively little preferential leaching of alloy components by liquid lead. Alloys containing molybdenum were unique in that no molybdenum was found in the mass transferred metal from these specimens. Thus no molybdenum was detected in the plugs from loops containing 25 percent molybdenum-nickel and 50 percent iron-molybdenum. Among the iron-chromium-nickel alloys tested, only in the case of the 16 percent nickel-37 percent chromium-iron alloy was a marked difference observed in the compositions of the plugs and the original specimens. The nickel, chromium and iron contents in plugs from this alloy were 2, 65 and 33 percent, respectively.

Relative Resistance to Mass Transfer

The materials tested could be divided conveniently into three groups on the basis of their relative resistance to mass transfer. The first group included only columbium and molybdenum. Neither of these metals suffered noticeable mass transfer or corrosion under the test conditions. A transverse section of the hot-leg specimen from a molybdenum loop is shown in Figure 3.

All of the alloys which exhibited a greater resistance to mass transfer than their pure metal constituents were included in Group 2. These were types 410 and 446 stainless steels, a 2 percent silicon-14 percent chromium-iron alloy, Hastelloy B (5 percent iron-28 percent molybdenum-nickel), 25 percent molybdenum-nickel, 45 percent chromium-cobalt, 50

percent molybdenum-iron and 16 percent nickel-37 percent chromium-iron (austenite and sigma). In addition, for reasons to be discussed below, the 50 percent iron-50 percent chromium alloy also was counted as a member of Group 2.

Group 3 consisted of nickel, titanium, cobalt, chromium, iron and beryllium in addition to the following alloys: Types 304, 310 and 347 stainless steels, Inconel, Nichrome V and 30 percent iron-nickel. A relatively low resistance to mass transfer was characteristic of the members of this group, the plugging times for the alloys being approximately those which might be predicted on the basis of the data for their pure metal constituents. The metals in this group also suffered relatively severe intergranular attack, as is illustrated in Figure 4, which shows a transverse section of the hot-leg of a type 304 stainless steel loop.

Special comment should be made concerning the results obtained for beryllium. During the operation of the beryllium loop, some of the SiO_2 from the walls of the loop itself was reduced by the beryllium. A thin layer of elemental silicon was found between the solidified lead and the walls of the loop at the end of the experiment. The effect of the reaction on the quantity of beryllium which underwent mass transfer is unknown. However, a large amount of beryllium was found in the cold leg of the loop, and it was concluded that beryllium probably would suffer considerable mass transfer in liquid lead even in a completely inert container.

One conclusion which can be drawn immediately from the experimental results is that nickel and nickel-based alloys (except for the special case discussed below) have a very low resistance to mass transfer in liquid lead. This fact is illustrated by the plugging time of only two hours for the loops containing pure nickel. Similarly rapid mass transfer was observed in the Inconel and Nichrome V loops as well as the type 300 series stainless steels tested. The latter alloys, while not nickel-based, are rich in nickel. Poor resistance to mass transfer also was found for other common alloying metals such as iron and chromium.

These facts made all the more surprising the observation that the alloys in Group 2 showed a large increase in resistance to mass transfer as compared to their pure constituents. The best example of this phenomenon was furnished by the 45 percent chromium-55 percent cobalt alloy. Loops containing pure cobalt and chromium plugged after 80 and 100 hours, respectively, yet in combination these two metals produced an alloy which after 765 hours still had not undergone enough mass transfer to cause plugging of the loop.

Intermetallic Compounds

A survey of the phase diagrams for the alloys tested provided a possible explanation for this effect. It was found that the compositions of the Group 2 alloys either coincided with those of intermetallic compounds or else were very close to compositions of intermetallic compounds. The alloys in Group 3, on the other hand, either formed no compounds or

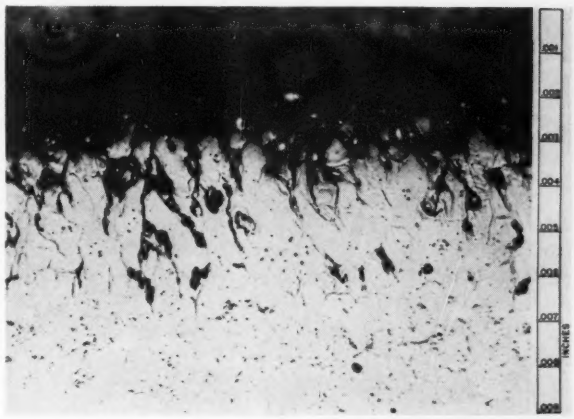

Figure 4—Transverse section of hot-leg specimen from lead-304 stainless steel loop. 255X.

else possessed compositions far removed from those of possible intermetallic compounds. Thus chromium and cobalt, which in a 45-55 ratio, exhibited a relatively high resistance to mass transfer, form a compound CoCr which is the dominant phase in the 45 percent chromium-55 percent cobalt alloy. Conversely, Nichrome V (20 percent chromium-80 percent nickel), in which no compound formation occurs, showed a relatively low resistance to mass transfer.

This hypothesis was tested with a specially prepared nickel-chromium-iron alloy. The composition 16 percent nickel-37 percent chromium-47 percent iron was chosen because with the proper heat treatment test specimens could be prepared either with or without the presence of an intermetallic compound. The test material was obtained in the form of a rod and was annealed at 1200 C and quenched from temperature. The two-phase alloy (austenite and ferrite) thus produced was machined into tubes suitable for testing. One set of tubes was annealed at 775 C producing a ferrite-to-sigma transformation and leaving the specimens as a predominately austenite-sigma alloy.

As may be seen in Figure 2, the austenite-sigma specimens exhibited a greater resistance to mass transfer than did those consisting of austenite and ferrite only. Thus two alloys, identical in composition but differing in that one contained an intermetallic compound (sigma phase), showed a marked difference in resistance to mass transfer. This result was considered especially remarkable in view of the high nickel content of the alloy.

A transverse section of the hot-leg specimen from a 16 percent nickel-37 percent chromium-47 percent iron (sigma and austenite) loop is shown in Figure 5. The sigma phase occurred as islands in an austenite matrix. The attack of the lead on the specimen occurred predominantly along channels which had been filled with matrix material. At the lead-specimen interface grains of sigma may be seen almost completely surrounded by the lead, thus demonstrating the resistance to attack exhibited by the intermetallic compound phase.

That the austenite-ferrite form of the 16 percent

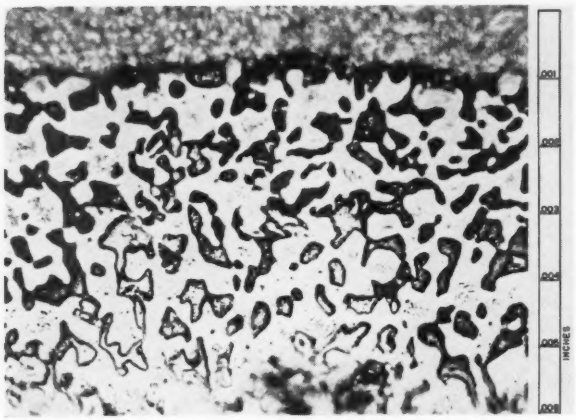

Figure 5—Transverse section of hot-leg specimen from lead-16 percent nickel-37 percent chromium-47 percent iron loop. 380X.

Figure 6—Transverse section of 50 percent chromium-50 percent iron specimen showing extensive crack network. Specimen was annealed for 288 hours at 785 C. 100X.

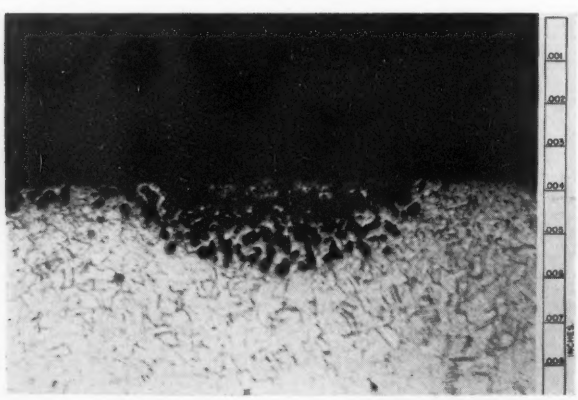

Figure 7—Transverse section of pre-oxidized hot-leg specimen from lead-347 stainless steel loop. 250X.

nickel-37 percent chromium-47 percent iron alloy possessed as high a degree of resistance to mass transfer as was observed was probably due to the fact that the ferrite-to-sigma transformation temperature is approximately 800 C. Since the hot-leg temperature for the loops was also about 800 C, some sigma phase was formed in the ferrite-austenite samples during the operation of the loops. Had this not been the case, it is likely that the plugging times for the ferrite-austenite loops would have been considerably shorter.

Despite the fact that their compositions lie slightly outside of the ferrite-sigma region of the iron-chromium phase diagram, both types 410 and 446 stainless steels exhibited a relatively high resistance to mass transfer. No trace of sigma phase was found either metallographically or with x-rays in these alloys. It is possible, however, that the observed effect was produced by a surface film of sigma too thin to be detected by the usual procedures.

The only alloy which provided an exception to the above rule was the 50 percent iron-50 percent chromium. This composition was chosen because it represented the theoretical composition of sigma phase. It was expected that the alloy would show a high resistance to mass transfer. Instead, plugging occurred after only 35-40 hours of operation.

Cracks in Alloy

A completely satisfactory explanation for this result has not been found, but it was thought that the short plugging time might be associated with the extreme brittleness of the test specimens. As may be seen in Figure 6, the test specimens before contact with lead were interlaced with an extensive series of cracks typical of sigma phase. During the operation of the loops lead seeped into these cracks, apparently increasing still further the brittleness of the alloy. When the excess lead was removed from the specimens at the end of the experiment, they were so friable that they virtually crumbled to the touch.

It was observed also that the amount of mass transferred material was only about one-fourth of that usually required for plugging. For these reasons it was thought possible that a small particle of metal was partially dislodged from one of the test specimens by the erosive action of the flowing lead. In such an event the circulation of the lead could have been sufficiently impeded to produce the premature freezing of the cold leg. It was not possible to verify this hypothesis directly, however, since the friability of the test specimens was sufficiently great to cause small particles to be broken off the specimens during the removal of the excess lead.

Despite the result obtained with the 50 percent iron-50 percent chromium alloy, it was concluded that the existence of a strong tendency toward intermetallic compound formation or the presence of an intermetallic compound in an alloy reduced the activity of the alloy compounds to such an extent as to increase markedly the resistance to mass transfer of the alloy. Conversely, when the alloy composition was such that no tendency toward compound formation existed, the resistance to mass transfer of the alloy was approximately that which might be predicted from the data for its constituents.

Influence of Oxide Films

The influence of the presence of moderately heavy oxide film in determining the resistance to mass transfer of a metal also was tested. The metal speci-

mens were oxidized in air until, judging from the interference tints produced, they were covered by an oxide film 1000 Å or more thick. It was found that such treatment increased the plugging times for the alloys tested. Thus loops containing preoxidized types 304 and 347 stainless steel specimens were operated in excess of 500 hours without the occurrence of complete plugging. The oxide apparently acted as a physical barrier between the lead and the metal. A transverse section of the hot-leg specimen from a pre-oxidized type 347 stainless steel loop is shown in Figure 7. The fan-like shape of the corroded areas may be seen clearly, suggesting that attack began at a break in the oxide film and spread outward.

Although it was apparent that the presence of a relatively heavy oxide film on the metal surfaces retarded mass transfer, it was recognized that this effect was of little practical value. In addition to the barrier to heat transfer which such oxide films would constitute in a heat exchanger, it is doubtful that a crack-free oxide coating could be maintained in a system under the erosive action of a flowing liquid metal or under the thermal strains produced by temperature gradients in the system. One loop was operated in which the lead was not deoxidized although it was filtered to remove any large particles of lead oxide. No appreciable improvement in resistance to mass transfer was observed in this case.

Conclusions

Of 24 metals and alloys tested in liquid lead, only molybdenum and columbium were found to possess a high degree of resistance to mass transfer. The common structural and alloying metals such as iron, chromium and nickel were very inferior in this respect. Certain alloys of these metals, however, exhibited a considerably higher resistance to mass transfer than could be predicted from properties of their pure metal components. This phenomenon was correlated with the existence of or a tendency toward intermetallic compound formation in the alloys.

Reference

1. J. V. Cathcart and W. D. Manly. A Technique for Corrosion Testing in Liquid Lead. *Corrosion*, **10**, 432-4 (1954) Dec.

Any discussions of this article not published above will appear in the June, 1956 issue.

TECHNICAL PAPERS ON CORROSION WELCOMED

Authors of technical papers on corrosion are invited to submit them for review without invitation to the Editor of Corrosion. Write for "Guide for the Preparation and Presentation of Papers" sent free on request to prospective authors.

Corrosion of Stainless Steel in Ferric Chloride Solution*

By H. A. LIEBHAFSKY and A. E. NEWKIRK

Introduction

IN A RADIOGRAPHIC investigation of the pitting of stainless steels in ferric chloride solution,[1] the authors were impressed by the large amount of metal that could be dissolved without altering greatly the appearance of an immersed coupon. For example, one usually acute observer guessed that the weight of such a coupon was 85 percent the initial, when the actual weight remaining was only one-fortieth that much. Figure 1 is intended to illustrate this situation, but it does this imperfectly, owing to the unavoidable wrinkling and breaking of the fragile remains of the coupon during removal from solution, washing, and subsequent drying.

The three radiographs of Figure 2 add to the qualitative description of the corrosion process by showing how internal removal of metal has proceeded to 25, 53, and 85 percent of completion (based on initial weight) in three different coupons. It is significant that the corrosion process is reproducible enough in its main features that the three coupons almost might be mistaken for a single specimen at three different stages in its life. These main features are: (1) attack at many localized points along sides and bottom, which results in the removal of relatively little metal, probably because this attack is not effectively accelerated by gravity; (2) a few pits near the top that grow downward under the influence of gravity and spread as they grow; (3) gradual envelopment, corrosion, and elimination of unattacked areas of metal (black in Figure 2c) as these pits grow. (Note how such areas disappear first near the top.)

The corrosion thus appears to involve rapid and extensive internal removal of metal initiated by relatively few pits, influenced by gravity, and accomplished through many small openings in surfaces that appear virtually intact by reflected light. Exploratory rate measurements on so interesting a process seemed well worth making.

The chemistry involved is, of course, complex. The ferric chloride solution used is acid by hydrolysis (initial pH near 1.3), and the species formed by hydrolysis are not well known. Chloride ion not only penetrates protective films, but forms complex ions as well. As corrosion progresses, the concentration of ferric species decreases, and ferrous, nickelous, and chromic ions (and their complexes) form.

Dissolved oxygen, present initially whenever the solutions were not deaerated, must disappear rather completely as corrosion progresses; in any case, the rate of oxygen supply by diffusion through the stagnant surface of the solution is far too low to support the corrosion rates observed. Although the presence of dissolved oxygen could have an initial influence on the corrosion process, probably through affecting the surface film on the coupon, the authors do not believe that this influence persists once corrosion has begun. The over-all corrosion reaction can be represented by the oversimplified equation:

$$M + nFe^{+++} = M^{n+} + nFe^{++} \qquad (1)$$

where M^{n+} may be Fe^{++}, Ni^{++}, or Cr^{+++}. Reaction (1) is the sum of the following half-cell reactions:

$$\text{Anode: } M = M^{n+} + nE$$
$$\text{Cathode: } nFe^{+++} + nE = nFe^{++}$$

In the above equations E denotes an electron.

It is well known that the anodic surfaces will be in contact with solutions differing greatly in composi-

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Abstract

Rapid corrosion occurs through pitting when annealed Type 302 stainless steel sheets are suspended in ferric chloride solution. Dissolution of sample can approach completion with unexpectedly little alteration in appearance of surface.

Rate of weight loss with different samples is surprisingly similar with the following four zones distinguishable in most cases: (1) a short induction period, (2) a zone of fairly constant, slow rate, which changes slowly into, (3) a zone of rapid rate, and finally (when less than 2 percent of the sample remains) into (4), a zone in which the rate is negligible.

Distinct rate zones do not exist if one side of the stainless steel plate is covered with a thin film of evaporated gold. Corrosion then is rapid at the outset, and the rate gradually decreases.

Induction-period experiments done with the aid of a microbalance show that corrosion begins within one minute after a clean dry coupon is immersed in ferric chloride solution. It has been demonstrated that measurements of corrosion rate in this system are simple and relatively reproducible. Extension of these measurements should yield valuable fundamental information about this corrosion process.

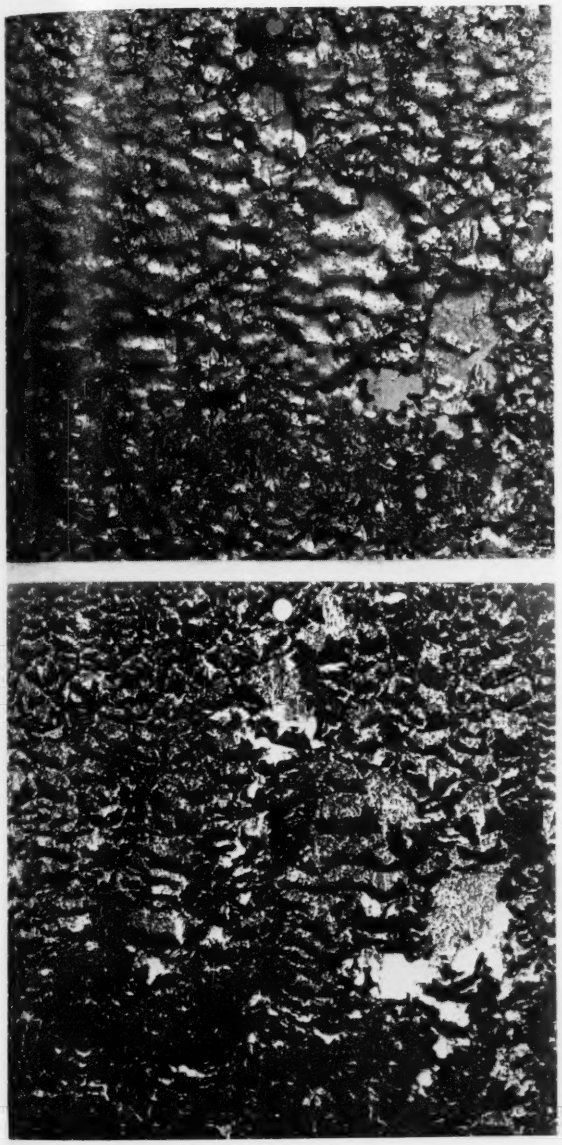
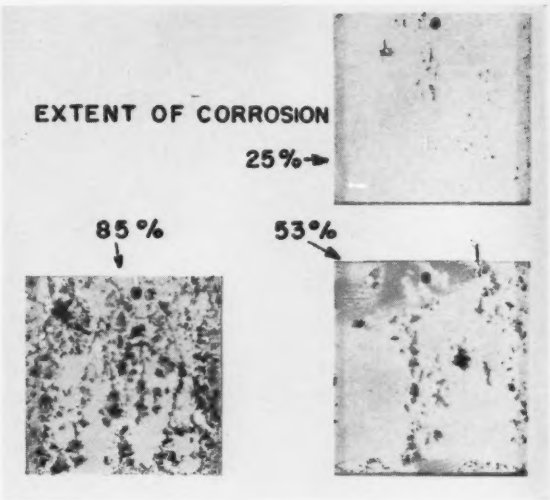


Figure 1—Sample from Run 1 after cessation of corrosion. Top photo shows sample under reflected light; bottom photo shows same specimen but with transmitted light. 2X.

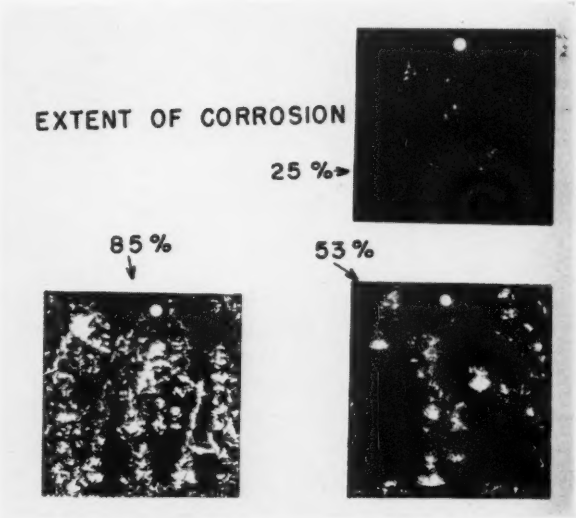
tion from the initial ferric chloride solution, and that these solutions will be relatively concentrated in the chlorides of the reaction products in Equation (1). Also, in most of the authors' experiments, the entire solution changed markedly in composition as corrosion progressed.

Rate Measurements

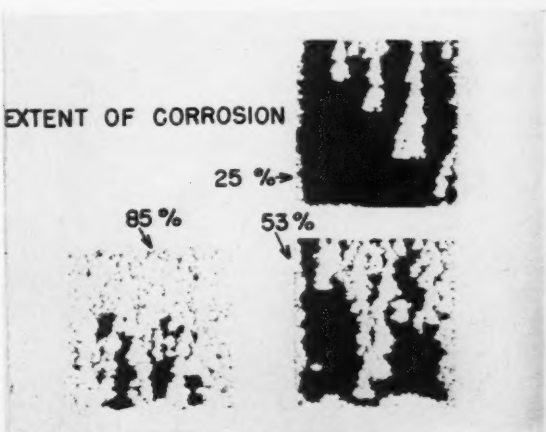
Neither the complex chemistry of the corrosion process nor the erratic nature of pitting in general looked favorable for the obtaining of reproducible rate measurements. Nevertheless, the rates were measured at which squares (0.0625 cm thick) of Type 302 stainless steel (nominal composition: 0.08-0.20 percent carbon, 17-19 percent chromium, 8-10 percent nickel, up to 2 percent manganese) lost weight



A—Reflected Light



B—Transmitted Light



C—Radiograph

Figure 2—Samples from Runs 14, 13 and 15.

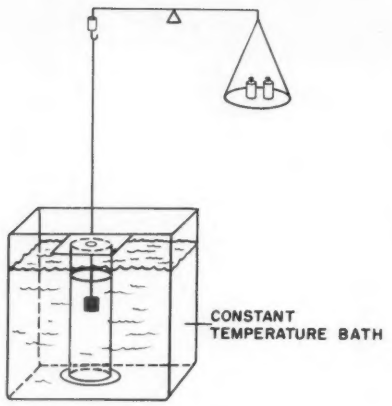


Figure 3—Test apparatus.

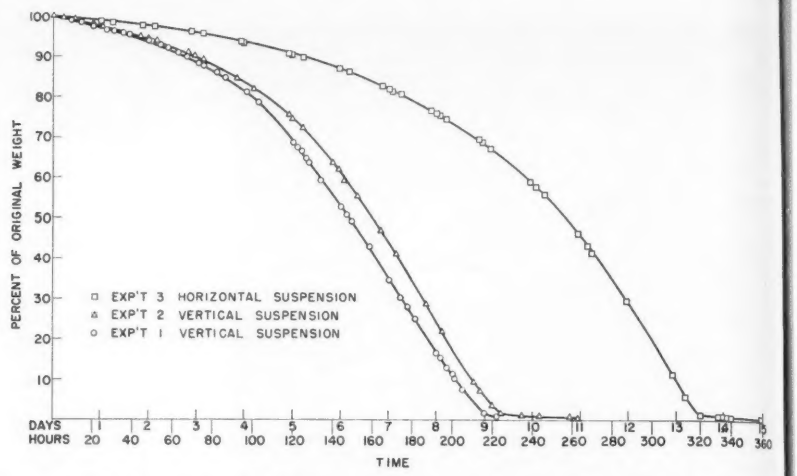


Figure 4—Rate of corrosion of Type 302 stainless steel in 10 percent ferric chloride hexahydrate solution.

when suspended at 30 C in a solution initially containing 10 percent by weight of $FeCl_3 \cdot 6H_2O$. In a standard experiment (Figures 3 and 4), the square was 5 cm on a side; the sample was suspended vertically by means of a nylon thread joined to the arm of a simple analytical balance. Some 1800 cc of the ferric chloride solution was contained in a 2-liter graduate and readings were taken at convenient intervals until the weight loss became negligible. Changes in weight of 1 mg, or of about 0.01 percent the initial weight of a standard coupon, could be detected with certainty even when corrosion was rapid.

The results of the first experiment are given in complete detail in Table 1 because they illustrate capability of the experimental method and show several striking features that led to further investigation. By use of the initial immersed weight of the coupon, balance readings were converted into percent of initial weight remaining from which data rates were then calculated as indicated at the foot of Table 1. No corrections were applied. Corrections for changes in buoyancy (probably not large) could not be made because the data necessary are unknown—not only does the density of the solution in the pits differ from that outside, but that outside varies from point to point, and with time.

The features of greatest interest in Table 1 are the following:

1. The fluctuations in the individual rates are surprisingly small. Except for the initial values, which cannot be precise because the intervals are too short, the individual rates give the impression of a process proceeding smoothly.

TABLE 1—Detailed Results for Experiment 1

Time (Hour)	Percent Initial Weight	Rate[a] Percent/ Hour	Time (Hour)	Percent Initial Weight	Rate[a] Percent/ Hour	Time (Hour)	Percent Initial Weight	Rate[a] Percent/ Hour
0.00	100.00	....	32.7	96.13	0.13	144.0	52.89	0.68
0.40	99.96	0.11	34.2	95.93	0.15	146.8	51.02	0.65
0.55	99.94	0.13	37.8	95.37	0.16	149.5	49.29	0.67
0.70	99.92	0.17	38.0	95.33	0.15	152.2	47.39	0.73
0.85	99.89	0.14	38.4	95.28	0.16	158.0	43.08	0.75
1.4	99.82	0.15	47.9	93.73	0.16	168.5	35.12	0.78
1.6	99.78	0.20	49.0	93.55	0.16	173.9	30.63	0.79
1.7	99.76	0.17	50.4	93.32	0.17	177.3	28.14	0.78
1.9	99.73	0.16	51.6	93.12	0.16	181.0	25.11	0.78
2.4	99.65	0.14	53.8	92.76	0.18	192.0	16.66	0.76
3.1	99.56	0.14	55.8	92.37	0.20	193.8	15.40	0.69
3.4	99.51	0.14	57.6	92.00	0.22	195.5	14.24	0.66
4.2	99.41	0.13	62.0	91.01	0.24	197.2	13.17	0.64
4.8	99.33	0.13	72.7	88.43	0.24	197.6	12.90	0.64
5.3	99.27	0.13	75.2	87.80	0.26	199.7	11.57	0.63
5.9	99.19	0.12	82.1	85.95	0.28	201.4	10.50	0.65
6.6	99.11	0.12	85.8	84.78	0.33	205.3	7.94	0.59
7.0	99.06	0.12	97.0	80.99	0.35	216.1	1.87	0.56
7.8	98.96	0.12	103.2	78.72	0.39	216.6	1.66	0.37
9.0	98.81	0.12	108.6	76.50	0.59	217.3	1.43	0.32
14.0	98.22	0.11	120.0	68.81	0.67	217.6	1.34	0.15
23.6	97.17	0.11	122.1	67.51	0.61	218.6	1.23	0.07
25.5	96.97	0.11	123.8	66.50	0.63	219.3	1.22	0.02
27.4	96.77	0.11	126.5	64.72	0.64	219.6	1.21	0.02
28.6	96.64	0.11	128.3	63.63	0.66	220.7	1.19	0.02
30.7	96.40	0.12	134.3	59.55	0.68	221.8	1.17	0.02
31.0	96.35	0.14	....	....	....	222.6	1.15	0.02

[a] Rate at time $t_n = \dfrac{(\text{Percent Initial Weight})_{t_{n-1}} - (\text{Percent Initial Weight})_{t_{n+1}}}{t_{n+1} - t_{n-1}}$,

Where n = any observation,
n-1 = previous observation,
n+1 = next observation.

2. The rate increases progressively until about 90 percent of the coupon has disappeared.

3. Any induction period must be short. The first corrosion rate in Table 1 differs but little from those measured during the next 30 hours.

4. Near the end (in the period from 216 to 219 hours), there is a precipitate decrease in the rate.

Particularly surprising was the long-continued increase in rate, for this increase occurred in the face of a great decrease in the weight of metal left to be corroded. There was also a marked decrease in the ferric chloride concentration. (Note that complete dissolution of 14 grams of iron requires 135 grams of $FeCl_3 \cdot 6H_2O$, based on Equation 1.)

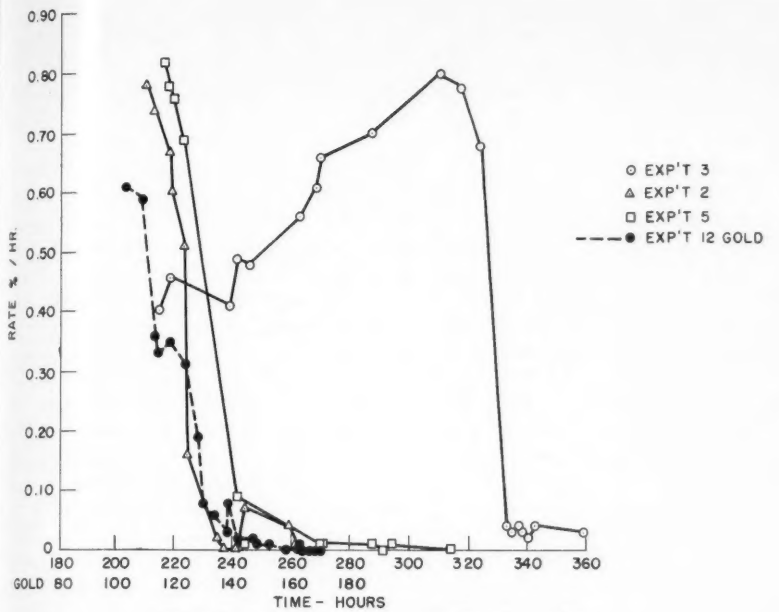


Figure 5—Corrosion rates near cessation of corrosion.

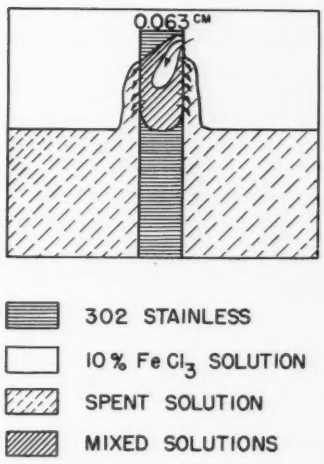


Figure 6—Model of corrosion pit.

TABLE 2—Summary of Corrosion Rates at Three Stages in Reaction

Exp't	Coupon Weight[a] (g)	Coupon Area[b] (cm^2)	10^4 x Rate in g/hr/cm^2[c] 0-10% Complete[d]	45-55% Complete[d]	80-90% Complete[d]
1	12.95	53.40	3.7	16.7	16.7
2	12.85	53.00	3.4	17.3	18.7
3	12.87	53.04	2.0	13.5	18.7
5[e]	3.22	13.59	3.2	16.9	19.7
6	0.079	0.44	5.8	11.6	6.7
7	0.067	0.38	17.4	14.5	17.4
9[e]	0.136	0.70	7.2	38.9[f]	19.4
10	0.121	0.63	7.5	20.8	25.5
11	12.74	52.52	2.8	12.1	12.4
12	12.77[g]	52.67	44.1	20.7	10.8
13[h]	3.19	13.49	4.9	19.9[i]	Not taken
14[h]	3.13	13.24	4.4	Not taken	Not taken
15[h]	3.20	13.52	4.3	20.6	21.5[j]

Notes
[a] Weight in air.
[b] Total area. Edges and peripheral area of hole included.
[c] An average rate for the interval listed. Two exceptions as noted.
[d] Intervals defined by degrees of completion expressed as percent initial weight lost.
[e] Experiments 4 and 8 wholly unreliable.
[f] Increased rate concomitant with increased concentration of solution owing to evaporation. See text.
[g] Weight of gold (0.031 gram; calculated thickness, 7.5 x 10^{-5} cm) not included.
[h] For radiograph of coupon at end of experiment, see Figure 2.
[i] Average rate for 45-53 percent completion.
[j] Average rate for 80-85 percent completion.

Experiment 3 was essentially different from Experiment 1 only in that suspension was horizontal (from a hole in each corner) rather than vertical. There is good evidence (Figures 1 and 7 in Reference 1) that horizontal immersion will produce by far the greater number of active pits. It is clear from Figure 4 that the rate was considerably lower with horizontal immersion, although the maximum rate agrees with that of Experiment 1. This is regarded as evidence that the corrosion rate does not depend upon the number of pits.

In Figure 4 the data for each experiment correspond to those in the first two columns of Table 1. The rate at any point in an experiment is the slope of the curve at that point. Curves obtained in other experiments resemble those in Figure 4 with the exception of Experiment 12. Furthermore, the figure is a fair guide to reproducibility in all cases except those in which the smallness of the coupon brought added difficulties in measurement.

Corrosion Rate and Cathode Area

Further insight into the corrosion process was sought by investigating the dependence of rate on coupon area. The reasoning is as follows: Possible polarization at anodes and cathodes can be ignored. The number of anodes (pits) on any coupon is unpredictable and seems not to govern the rate. When corrosion begins, the total anodic area must be very small, yet the corrosion rate very soon assumes a value that it maintains for many hours even though the total anodic area is growing to many times its initial value. Rate and anode area thus seem to be independent.

Perhaps processes at the cathode limit the over-all corrosion once pits are established. This idea is attractive because the cathode area, which cannot be much different from the coupon area in the early stages of corrosion, is not subject to rapid change. The fact that a coupon retains its shape when 98 percent of it has disappeared argues that all the outer surfaces must be cathodic. If the reasoning in this paragraph is correct, over-all corrosion rate and cathode area should be proportional.

Although cathode area and coupon area need not be identical, they should be comparable, at least in the early stages. Consequently, the reasoning of the foregoing paragraph may be tested by determining if the corrosion rate per unit area (e.g., grams consumed/hr/cm^2) is reasonably constant. Rate data in these units are summarized in Table 2 at three stages in the corrosion reaction for all experiments except two that were discarded as wholly unreliable.

Attempts were made to keep solution volume and coupon weight proportional. It proved impractical to

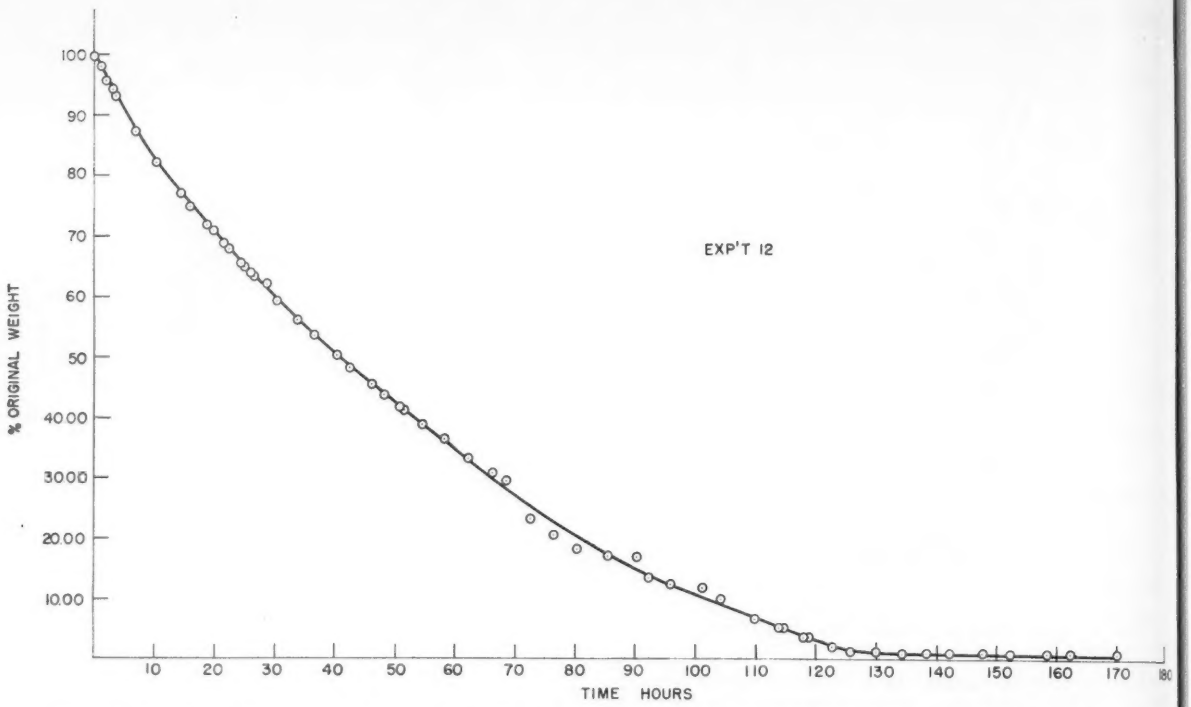


Figure 7—Corrosion of Type 302 stainless steel (partially gold-plated). The solution contains 10 percent ferric chloride hexahydrate.

do this with the four lightest coupons, however, and different volumes were used there in the hope that experimental conditions would be improved. (The consequence was, of course, that the concentration of ferric ion did not vary with time in the way in which it did with the larger coupons.) In these four cases the expected difficulties arising from surface-tension effects on the suspension were met. A fine quartz fiber proved the most satisfactory suspension, and a torsion balance (capacity, 0.1 gram) was used.

It seems clear that results for the four lightest coupons are the least certain, and that Experiment 3 (horizontal immersion) and Experiment 12 (one side of coupon gold-plated) cannot be used to establish the area hypothesis. (The authors are inclined to exclude Experiment 11 also. The coupon for this experiment was pickled in strong hydrochloric acid before the run; no explanation can be offered as to why this should reduce the rate of corrosion.) It is believed that the relevant data in Table 2 show that at all three stages of reaction a rough proportionality exists between corrosion rate and coupon area, and that this may be interpreted as a proportionality between corrosion rate and cathode area.

In Experiment 9, unwanted evaporation caused considerable concentrating of the solution. The rate of corrosion rose (see Table 2), and then decreased when the water lost by evaporation was replaced. This is regarded as evidence that the rate increases with the concentration of ferric chloride.

Last Stages of Corrosion

Figure 5 shows, on a magnified scale, data for the final stages of the corrosion reaction in several experiments. In each such case, but least in Experiment 12 (to be discussed later), the rate in the units of Table 1 decreased precipitously as the uncorroded metal approached exhaustion. It is reasonable to regard the decrease in rate as caused by a rapid shrinking of the total effective anode area.

Corroboration of this view was obtained by studying an air-dried residue resembling that of Figure 1. X-ray diffraction patterns for the residue showed well-defined lines characteristic of the stainless steel, and a few faint reflections that could not be identified. A portion of this residue was treated with strong hydrochloric acid until gas evolution ceased. If the gas consisted entirely of hydrogen, the residue was about one-sixth uncorroded metal; this metal corresponded to less than 0.2 percent of the initial coupon. The residue thus consisted mainly of oxidized metal, which might be expected to shield from attack the last portions of unoxidized metal. Accordingly, it seems all the more remarkable that only about 0.2 percent of metal (or 20 mg for a standard coupon) should remain uncorroded when the corrosion rate becomes negligible.

Tentative Mechanism

Many features of the following mechanism were postulated in the course of the radiographic investigation,[1] but it seemed advisable to withhold publication until the evidence from the rate measurements was in.

Figure 6 is a sketch that shows the idealized mechanical features, as the authors envision them, of the corrosion process in an intermediate stage. Of course, concentration gradients (not shown) exist

in all solutions (for example, the concentration of ferric chloride will increase more or less continuously as one moves from the bottom to the mouth of the pit, and the concentration of corrosion products in the unstirred solution will be greatest near the coupon).

The following simplified life history of a pit is in accord with Figure 4. After the film initially present on the coupon has been broken, perhaps owing to penetration by chloride ion, escape of cations from the metal into the solution begins and pits form. Initially, the corrosion products move out through the mouth of the pit. As corrosion proceeds and the pit deepens, this egress becomes more difficult. Corrosion products then concentrate in the pit, electrical neutrality being maintained through transference of chloride ion. The solution in the pit becomes increasingly dense, and, owing to the action of gravity, the pit grows downward and broadens. (Note the "pine trees" in Figure 2.) As the walls of the pit grow thinner and thinner, they eventually rupture under the influence of mechanical and electrical factors. The corrosion products can then stream out as shown in Figure 6.

The anodes support a surprisingly high corrosion rate when they are very small, both in the initial (Table 1) and in the final stages (Figure 5). This argues against appreciable polarization and is in accord with the idea that the anode reaction, which is the escape into the solution of a cation that becomes hydrated, is simpler than the cathode reaction in this system.

The cathode reaction is the transfer of an electron to some ferric species, say to Fe^{+++}. The electron probably has to penetrate a surface film, and the nature of this film therefore will help determine the extent of polarization at the cathode. Furthermore, the Fe^{+++} will have to be brought to the cathode surface, and the rate of the cathode process ought therefore to be diffusion-limited. This hypothesis is the simplest explanation of the proportionality between rate and cathode area.

In the initial stages, cathode area and coupon area differ little from each other. As corrosion progresses and internal surfaces are created, it is logical to assume that some of these internal surfaces can act as cathodes also—especially when they are in contact with solution rich in Fe^{+++}. This increase in cathode area could be enough to explain the increased rate of corrosion observed as an experiment progresses. But it is likely that part of the increased rate must be credited to the flow of solution made possible by the perforation of the coupon walls (Figure 6). Such flow not only speeds up macroscopic transfer, but it acts also to reduce the thickness of the liquid layer through which diffusion must occur in connection with the cathode reaction.

TABLE 3—Corrosion Rates in the Early Stages of Experiment 12

Time (Hour)	Percent Initial Weight (g)	Rate[a] Percent/Hour
0	100.00	....
0.067	99.88	2.00
0.150	99.70	2.07
0.217	99.57	1.88
0.267	99.48	1.93
0.367	99.28	1.90
0.483	99.07	2.12
0.617	98.75	2.00
0.733	98.57	1.76
0.867	98.31	1.69
1.000	98.12	1.98

[a] Rate in units of Table 1 and calculated as shown there. Weight of gold deducted before rates were calculated.

In the foregoing picture, then, it is assumed that the reaction at the cathode always limits the corrosion rate; the anodes, once they are established, can support a higher rate than that observed. As corrosion progresses, the rate increases owing to the generation of internal cathode area and to increased flow of solution through and near the coupon. That this increase of the rate should vary with coupon size (Table 2) is not surprising; flow must depend on coupon size as must the extent of internal area generated, and the proportion of external area contributed by the edges and by the hole increases as the coupon becomes smaller. Similar reasoning can account for the difference between vertical and horizontal immersion.

Effect of Partial Gold-Plating

In order to see whether a radical change in the cathode surface would affect the rate of corrosion, an experiment was made on a standard coupon, one side of which had been coated with gold. Gold was chosen in the expectation that this noble metal would offer less hindrance at the surface than does stainless steel to the passage of electrons prerequisite to their capture by ferric ion.

Just over 0.03 gram of gold was evaporated onto one side of a standard coupon. Duplicate evaporation onto a glass slide revealed the absence of pinholes. The gold-plated coupon was run in a standard experiment on an initially degassed solution. (By this time, degassing was resorted to as a means of eliminating bubbles that otherwise formed on the coupon to make initial readings difficult.) Table 3 shows that the initial corrosion rate was markedly higher than that in Table 2.

The complete curve for Experiment 12 is given in Figure 7. Toward the end of the run, the separation of the solution into two layers (Figure 6) was more marked than in a standard experiment.

Tables 2 and 3, Figures 6 and 7, all testify to the marked effect of the gold-plating on the corrosion reaction. The initial rate was *increased* in this way more than fifteen-fold. The entire course of the reaction was changed: the rate then decreased as the reaction proceeded, and the abrupt termination (Figure 5) was absent.

In the authors' opinion, the increased initial rate was due to the greater ease of electron capture of ferric ion at a gold, as compared with a stainless steel, surface. That the rate fails to increase, and actually decreases, as corrosion of the gold-plated coupon progresses is attributed to: (1) reduced flow of the kind in Figure 5. The gold plate remains impervious to solution; (2) less internal cathode area; (3) formation of a ferrous chloride layer near the gold surface to hinder access of ferric ion; (4) reduction of the ferric chloride ion concentration. This suggested explanation obviously needs to be tested.

Acknowledgments

The authors thank Miss I. Aliferis for help with some of the measurements and with the computations, and T. Stack, Turbine Division Laboratory, for making the radiograph.

Reference

1. H. A. Liebhafsky and A. E. Newkirk. *Corrosion,* **9,** 432-435 (1953).

DISCUSSION

Discussion by Herbert Uhlig, Massachusetts Institute of Technology, Cambridge, Mass.

The unusual resistance of skin on cold rolled 18-8 shows up in several media in addition to ferric chloride. Some years ago[1] we attempted an investigation of the effect when we noticed that pitting of 18-8 in hot aerated NaCl solutions almost always occurred at the edges of a cold rolled flat specimen, but seldom, if ever, on the cold rolled surface itself.

It was thought that perhaps cold work in cutting the specimens accounted for a greater tendency toward corrosion at the edges where they might be made anode by shearing or sawing. Diminishing the width of the specimens still left the pits predominating at the edges, and, indeed, when small diameter cylindrical specimens were prepared, the pits still occurred at the original edges of the sheet. Annealing such cylinders reduced the tendency for pitting at the edges but did not eliminate it. This convinced us that preferred grain orientation produced by rolling was an important factor. I should be interested in any thoughts the authors may have in this matter.

It may be in order to mention that addition of 3 percent sodium nitrate to 10 percent ferric chloride completely inhibits pitting of 18-8. We have exposed specimens to such a solution for 17 years without evidence of crevice corrosion or pitting, and with only token weight loss.

[1] H. H. Uhlig and M. C. Morrell, *Ind. Eng. Chem.,* **33,** 875 (1941).

Reply by H. A. Liebhafsky and A. E. Newkirk:

Added evidence of the importance of preferred grain orientation in the corrosion of rolled stainless steel is provided by the "bow tie" pitting found in exploratory experiments on Type 347 rolled sheet (Figure 6 in Reference 1). For our rate work, we chose annealed Type 302 sheet to avoid orientation effects. Inasmuch as the coupons for our measurements were not re-annealed after being cut from a large sheet, corrosion at the edges was probably influenced by cold work of the metal during cutting. We doubt whether preferred orientation measurably influenced our rate measurements.

Edge effects generally seemed not to have much effect on rate except, perhaps, in the initial stages. One result of our work is to show that relatively few pits are required to support a high rate of corrosion. Pits often formed away from the edges; in this connection, note the great increase in the number of such pits when immersion was changed from vertical to horizontal (Figure 1 as companed with Figure 7 in Reference 1).

To summarize: We feel that the factors found by you to be important under experimental conditions different from ours could have had some initial influence on our rate measurements. We do not believe—chiefly because our rates were unusually reproducible—that these factors could have had a measurable effect for very long in any experiment.

Any discussions of this article not published above will appear in the June, 1956 issue.

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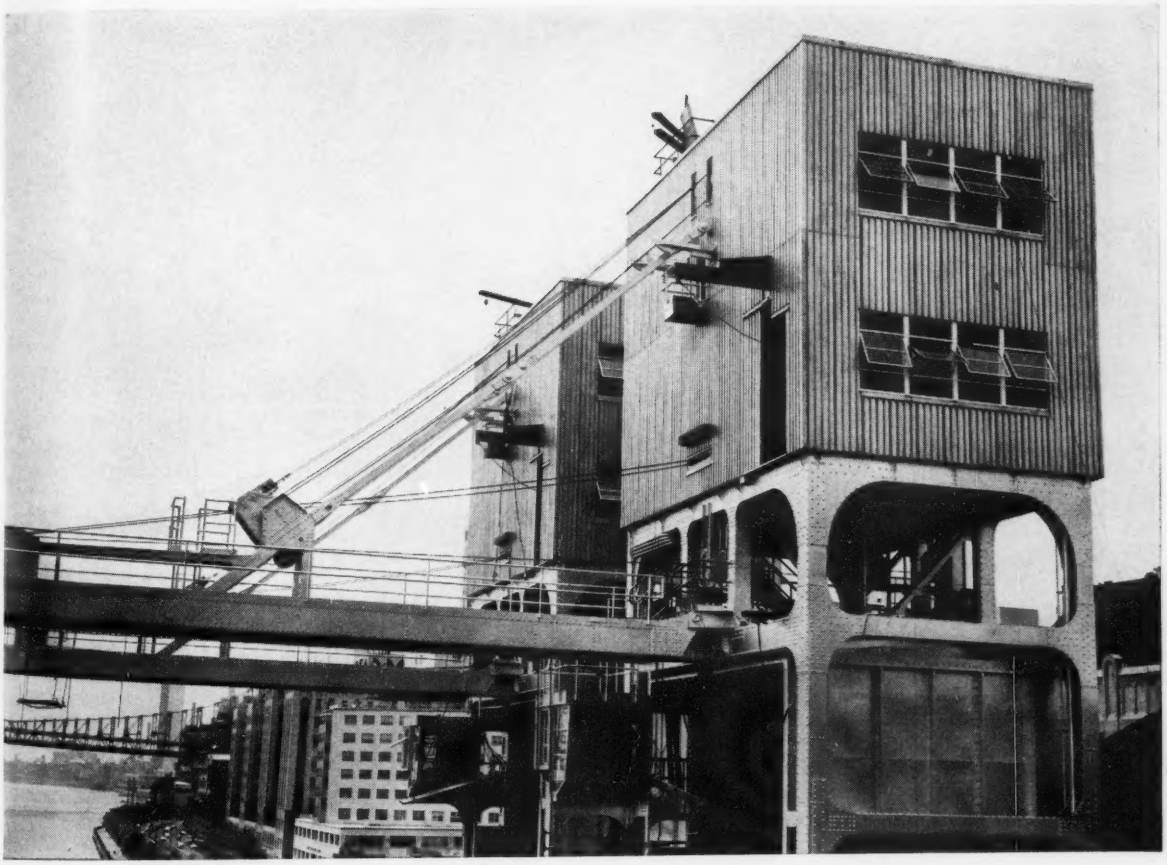

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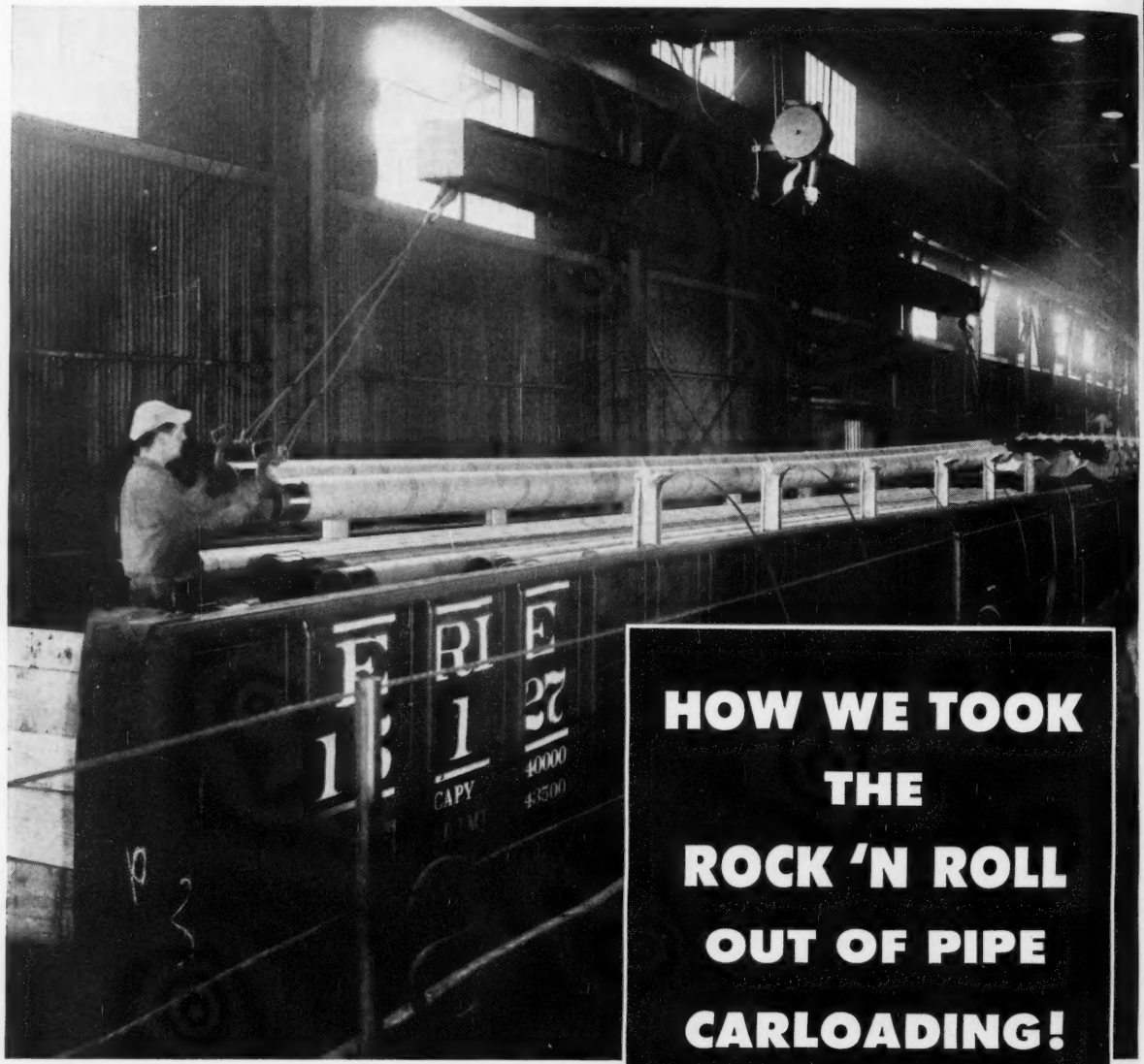

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Sour Crude Prediction Report Is Presented

New York Program Will Include Many Committee Papers

As has been the practice in the past, technical committees of NACE are contributing considerably to the formal technical program of the 1956 NACE Conference.

Unit Committee T-3F on Corrosion By High Purity Water has again organized a symposium on High Purity Water. While the papers to be presented at the symposium are not directly results of the committee's work, they are considered to be contributions to the work of the committee.

The five papers scheduled to be presented at the symposium are:

Corrosion Studies in High Temperature Water by a Hydrogen Effusion Method by M. C. Bloom, M. Krulfeld, W. A. Fraser and P. N. Vlannes, Naval Research Laboratory, Washington, D.C.

The Corrosion of Iron in High Temperature Water by D. L. Douglas, General Electric Research Laboratory, Schenectady, N. Y. and F. C. Zyzes, Knolls Atomic Power Laboratory, Schenectady, N. Y.

Corrosion of Stainless Steels in Supercritical Water by H. A. Pray and W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio.

Corrosion Resistant Aluminum Alloys for Use in Water at Elevated Temperatures, by J. E. Draley and W. E. Ruther, Argonne National Laboratory, Lemont, Illinois.

Aluminum Alloys for Handling High Purity Water by W. W. Binger and C. M. Marstiller, Aluminum Company of America, New Kensington, Pennsylvania.

Petroleum Production Symposium

Group Committee T-1 was responsible for organizing the Symposium on Oil and Gas Production. W. F. Oxford, Jr., of the Sun Oil Company of Beaumont, Texas and Jack L. Battle of the Humble Oil and Refining Company in Houston, Texas, chairman and vice-chairman respectively of T-1, are serving as chairmen of the symposium.

Papers scheduled to be presented are:

Concentration Cell Corrosion of Well Casing Joints by representative of Continental Oil Company, Ponca City, Oklahoma.

Casing Corrosion-Hugoton Gas Field by W. C. Koger, Cities Service Oil Company, Bartlesville, Oklahoma.

Cathodic Protection of Mobile Off Shore Drilling Platforms by E. P. Doremus, Cathodic Protection Service, Houston, Texas.

(Continued on Page 58)

Temporary Chairman Is Named for T-4B-3

J. C. Howell of the Public Service Electric & Gas Company, Maplewood, New Jersey has been ill and confined to the hospital. Mr. Howell has been chairman of NACE Task Group T-4B-3 on Tests and Service for several years.

Howell

D. R. Werner, American Telephone & Telegraph Company, Kansas City, Missouri, has been serving as vice-chairman of T-4B-3 and will assume duties as chairman during Mr. Howell's hospitalization. This committee prepared a technical report on Tests and Service for Lead Sheathed Cables in the Utilities Industry that was published in the December 1954 issue of CORROSION.

Technical Committees Have Another Record Year Of Activity During 1955

Technical committees of NACE have had another year of record activity. Meetings during the 1955 Annual Conference in Chicago in March were the first for most committees since the reorganization went into effect. More than 60 technical committee meetings were held during the conference week and they were better attended than usual. More publicity was given and excellent programs were outlined. Increased attendance produced livelier discussions than in the past and there was considerable comment on the increased value of the sessions.

Twenty-two technical committee meetings were held during the 1955 NACE South Central Region Meeting in Houston in October. Over 1000 attended this session of whom three-quarters registered during the two days set aside exclusively for technical committee meetings.

Two groups met during the northeast Region Meeting in November. All were well attended and it is expected more will be scheduled during future Northeast Region meetings.

Three committees convened during the November Western Region Meeting in San Francisco. Their membership is predominantly from the Western Region.

The Technical Practices Committee and the NACE Board of Directors suggests more NACE Technical Committees schedule sessions during regional meetings. It is the consensus this will

(Continued on Page 60)

Inhibitors Reduce Loss on West Texas-New Mexico Wells

A task group representing the West Texas-New Mexico area members of Unit Committee T-1B on Sour Oil Well Corrosion has presented a report to the unit committee. The task group reported methods used to predict corrosion in a sour crude field. Principally three methods are being used for prediction. These methods are: Examination of subsurface equipment, correlation of experience from similar fields producing from the same formation and determination of percent of water produced. Other methods used to predict corrosion include: Corrosion coupon tests, hydrogen sulfide determination, crude oil analyses and produced water analyses.

The task group reported the number of wells being treated by producing formations. These were as follows:

San Andras	284	Wolfcamp	8
Grayburg	182	Devonian	4
Yates	22	Glarietta	3
Tubb	17	El Capitan	3
Clearfork	13	Ellenburger	1

In the West Texas-New Mexico area injection of chemical inhibitors is the only method in general use for the control of corrosion. This is true primarily because of the good results obtained. Inhibitors for use in this area are selected on the basis of field tests, laboratory coupon and wetability tests and oil and water analyses. The amount of corrosion inhibitor used varies among the different operators. Some may use 150 to 200 ppm based on oil production; some use 50 to 350 ppm based on total fluid production; and some inject 1 quart per well per day.

Inhibitors have not eliminated bottom-hole pump corrosion but has reduced its severity. The frequency of inhibitor injection varies among the operators, but a majority use semi-weekly injection.

The West Kansas Task Group of Unit Committee T-1B report the opinion that one of the most important phases of inhibitor treatment is circulating time. Considerable work on this phase of the treatment procedure has been done and it was found that better protection can be obtained by circulating the well longer and treating less frequently with smaller amounts of chemical. Information to date indicates the inhibitor travels in slugs through the oil column in the annular space. If this is true, and there is some data to indicate it is, then wells are not being treated with a smaller concentration as was previously supposed, but with a high concentration for a short period of time. It was thought this might be the answer in part to the experience the operators have had with inhibitors that are not good in the various testing procedures at low concentration but give relatively good results in the field.

New York Program—

(Continued From Page 57)

Cathodic Protection Tests Made on Oil Well Casings at Kettleman Hills, California by J. K. Ballou, Standard Oil Company of California, San Francisco, California and F. W. Schremp, California Research Corporation, La Habra, California.

Steel Metallurgy Symposium

Unit Committee T-1F on Metallurgy is responsible for organizing the symposium on Steel Metallurgy and Corrosion. F. J. Radd of the Continental Oil Company, Ponca City, Oklahoma and F. L. Current of the Oil Well Supply Company, Oil City, Pennsylvania, respectively chairman and vice-chairman of T-1F are the chairmen for the symposium.

Papers scheduled to be given at the symposium are:

The Role of Iron Carbides and Impurities in the Corrosion of Plain Carbon Steels by D. A. Shock, F. J. Radd, R. L. McGlasson and L. H. Crowder, Continental Oil Company, Ponca City, Oklahoma.

Plastics Symposium

Unit Committee T-5D Plastic Materials of Construction has organized the plastics symposium. R. B. Seymour of the Loven-Chemical Company of California, Newhall, and G. Heinemann of the Columbia-Southern Chemical Corporation, Corpus Christi, Texas are the chairmen for the symposium. Mr. Seymour was first chairman of Unit Committee T-5D.

Papers scheduled to be given at the symposium are:

Introduction, R. B. Seymour of the Loven-Chemical Company of California, Newhall, California.

Properties and Performance of Thermoplastics in American Industry by J. F. Malone, B. F. Goodrich Chemical Company, Cleveland, Ohio and John McBride, Owens-Corning Fiberglas Corporation, New York, New York.

Properties and Performance of Reinforced Polyester Plastics in the Chemical Industry by R. E. Gackenbach and D. G. Estey, American Cyanamid Company, Bound Brook, New Jersey.

Impervious Graphite as an Engineering Material by W. W. Palmquist, National Carbon Company, Cleveland, Ohio.

Design and Engineering of Plastic Materials of Construction by R. P. Whittier and O. H. Fenner, Monsanto Chemical Company, St. Louis, Missouri.

The symposium on Power and Communications is not directly attributable to a technical committee, however, T. J. Maitland, American Telephone & Telegraph Company, New York, New York and W. A. Sinclair, Detroit Edison Company, Detroit, Michigan, chairmen of the symposium are officers of utility technical committees and all of the papers scheduled to be given at the symposium are authored by men who are very active on the utility committees.

Papers scheduled to be given at this symposium are:

Field Laboratory Testing of Wrappings for Buried Structures by H. M. Clayton, Memphis Light, Gas and Water Division, Memphis, Tennessee.

Corrosion of Lead Sheathed Power Cables in Concrete Tunnels by R. L. Perry, Commonwealth Edison Company, Chicago, Illinois.

Testing Methods and Corrosion Control Measures for Buried Telephone Cables by D. R. Werner, American Telephone and Telegraph Company, Kansas City, Missouri.

Corrosion Control Equipment for Underground Cables in Conduit in a Stray Current Metropolitan Area by E. P. Teale, American Telephone and Telegraph Company, Washington, D. C.

Ten Technical Reports Published by NACE During 1955

Seventeen technical committee reports were completed during 1955. Ten of these were published in 1955 issues of CORROSION, three in the January 1956 issue, and four are scheduled for publication in the next two or three months.

Reports published in 1955 were:

Tentative Standard Method for Measuring Electrical Conductance of Coating on Buried Pipe Lines, a Report of Technical Unit Committee T-2D on Standardization of Procedures for Meas-

(Continued on Page 64)

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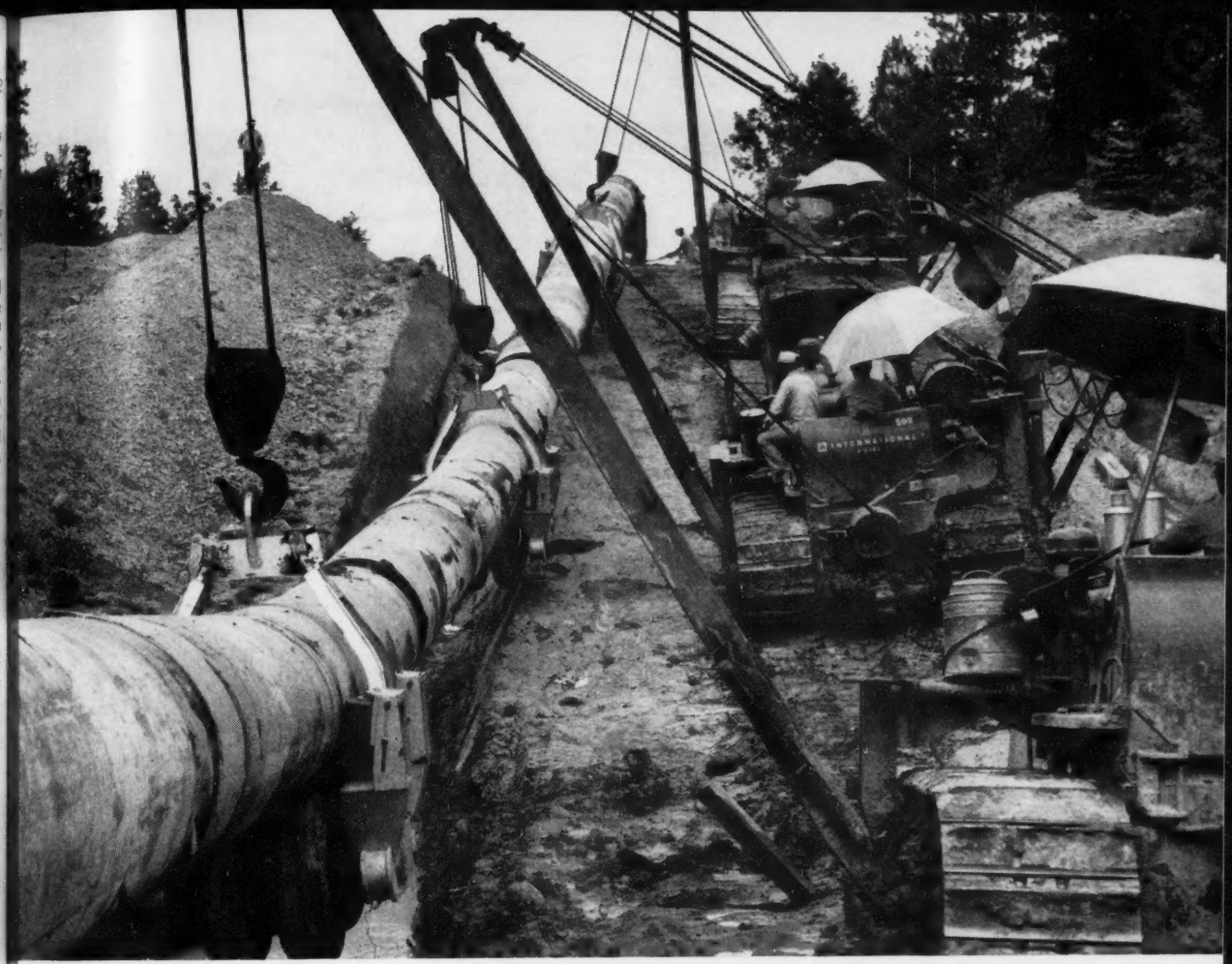

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Technical Committees—

(Continued From Page 57)

strengthen the organization and permit more members to participate in technical activities of the association.

New Committees Organized

Increased activity of the technical committees has attracted new members. Many have brought new corrosion problems or a willingness to work on existing problems. As a result several new technical committees have been formed whenever possible as task groups of existing unit committees. When the scope of an existing unit committee will not cover the new problem a new unit committee is added.

New unit committees added during 1955 include:

Technical Unit Committee T-1M on Corrosion of Oil and Gas Well Producing Equipment in Offshore Installations. It is interested in corrosion of equipment and installations used in offshore drilling and production. It endeavors to assemble and compile information on materials and techniques and makes such information available to those concerned. To date it has 29 members. In addition to several meetings a full day short course on surface preparation and application of protective coatings was held.

Technical Unit Committee T-2K on Prefabricated Plastic Film for Pipe Line Coatings. This committee was organized to prepare a history of experience on the use of prefabricated plastic films such as pressure sensitive tapes. It also will study bonding agents or adhesives and proper application when an adhesive or catalyzed bonding agent is applied to pipe and a plastic film is applied separately. Water osmosis created by cathodic protection, oil and hydrocarbon solubility of bonding agents, chemical resistance and other factors will be weighed.

Prefabricated plastic films now available and to be discovered will be studied, with special attention to plasticizers to help prevent use of a plasticizer that will cause a breakdown of an otherwise good film. Recommendations to manufacturers and users will be made. The unit plans also to investigate the moisture vapor transmission rate and chemical resistance of plastic films and to study the proper application of both pressure sensitive tapes and prefabricated films applied to pipe lines, specifically as pipe line coatings. Twelve members have held two meetings and task groups have been organized to study the various problems outlined in the scope.

Technical Unit Committee T-5E on Stress Corrosion Cracking of Austenitic Stainless Steel. The organizational meeting of this committee was held in Houston in October 1955, and the scope has not been completed.

New committees organized as Task Groups under existing Unit Committees during 1955 are:

T-5A-6 on HF Corrosion. This task group will consider problems of corrosion related to fluorine, hydrogen fluoride and hydrofluoric acid. Four project groups have been assigned the following related problems: 1) problems associated with the manufacture of HF, 2) problems of cracking tower corrosion, 3) problems associated with the production of agricultural fertilizers, and 4) process industry problems in handling HF.

T-5B-2 on Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry. There was so much interest in the activities that the second committee meeting evolved into a full day's session. It has compiled a bibliography and currently is preparing a progress report. It has a membership of 42 and applications for membership are still being received.

Unit Committee T-5D on Plastic Materials of Construction has appointed task groups on the following subjects: T-5D-1, Questionnaires; T-5D-2, Inorganic Acids; T-5D-3, Inorganic Alkalies; T-5D-4, Gases; T-5D-5, Water and Salt Solutions; T-5D-6, Organic Chemicals; T-5D-7, Engineering Design; T-5D-8, Methods and Criteria for Evaluating Plastics in Chemical Environments.

Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion has developed task groups on the following subjects: T-6A-1, Heavy Linings; T-6A-2, Vinyl Coatings; T-6A-3, Vinylidene Chloride Polymers; T-6A-4, Phenolics; T-6A-5, Polyethylene; T-6A-6, Rubber and Elastomers; T-6A-7, Silicones; T-6A-8, Methacrylates; T-6A-9, Furanes; T-6A-10, Polyesters; T-6A-11, Epoxys; T-6A-12, Fluorocarbons.

Unit Committee T-1C on Sweet Oil Well Corrosion has organized task groups on the following subjects: T-1C-1, Water Dependent Corrosion, Field Practices; T-1C-2, Water Dependent Corrosion, Experimental Aspects; T-1C-3, Water Independent Corrosion, Field Practices; T-1C-4, Water Inde-

(Continued on Page 61)

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Technical Committees—

(Continued From Page 60)

pendent Corrosion, Experimental Aspects.

Each task group assigned represents a new project initiated. In addition to these projects many more have been initiated where entire committees or single individuals are doing the work.

Membership Net Increase

During the year there has been a net increase of 113 members on technical committees. With current total committee membership at 941, this means a net gain of 13.7 percent during 1955. Some have membership in as many as ten different committees.

When the accumulated membership of all committees is totaled disregarding duplicate membership, the total is over 2000. As the results of committee work is published more NACE members will take active parts in the work, it is believed.

Changes in Committee Procedure

When the Technical Committee Operation Manual was put into effect in March 1954 it was realized the manual could and would be amended as changes became necessary. The Technical Practices Committee made several amendments to the manual at its meeting in Chicago in March, 1955. These included a revised method for electing group committee vice chairmen, revised method for electing unit committee officers, revised procedure for organizing new unit committees, revised method for approving technical reports, a section on liaison with committees of other organizations, a section on liaison between NACE committees and a section on amending the manual.

Reports Are Valuable

The most valuable publications resulting from technical committee work are the Technical Committee Reports. Reports published in CORROSION in 1955 are covered elsewhere. These reports occupied 49 pages of the 1955 volume of CORROSION. Many reprints of these reports have been sold on individual orders to interested persons.

The Technical Committee Activities Section of CORROSION is designed to keep the NACE membership informed of the activities of the technical committees. During 1955 approximately 125 articles in about 56 pages about technical committee activities appeared in this section of CORROSION.

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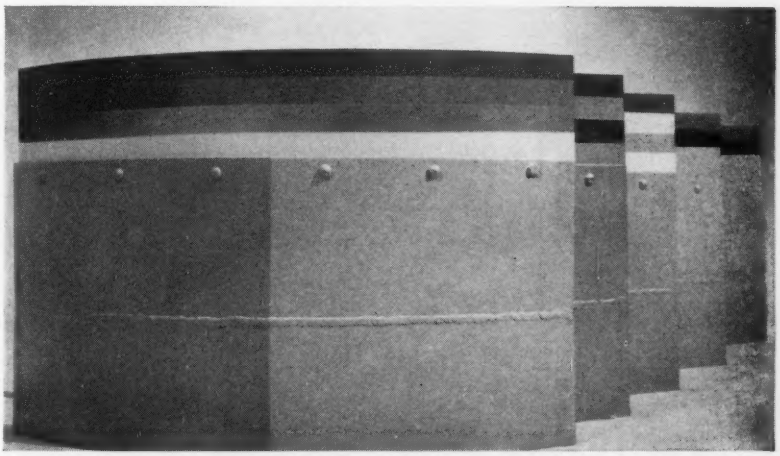

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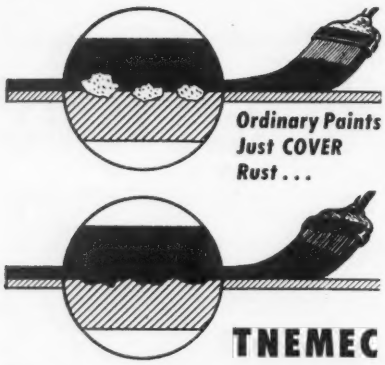

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Tentative Schedule of Technical Committee Meetings

(12th Annual Conference, New York, March 12-16)

Day	Committees Meeting
Monday	
Morning	T-1 T-2C,F,K T-4F T-5A-5,6 T-6A
Afternoon	T-1 T-2B,D,G T-3B,C T-4D T-4F-1 T-5A,-1,2,4 T-5B-2 T-6R
Tuesday	
Morning	T-1F,H T-2A-2 T-2H T-3D,-1,G T-4B-1,2,6 T-5A-3 T-5B,D T-6B
Afternoon	T-2A,E,J T-3H T-4B,-3,4,5 T-4E
Wednesday	
Morning	T-1C T-1D-1 T-3A,E,E-1 T-4A T-6C,H
Afternoon	T-1G,K T-3E-2 T-3F
Thursday	
Morning	T-1D T-5E T-6E,G,K
Afternoon	T-1B,J
Friday	
Morning	T-5B-2

T-1 Corrosion in Oil & Gas Well Equipment, All Day Monday

T-1B Condensate Well Corrosion, Thursday p.m.

T-1C Sweet Oil Well Corrosion, Wednesday a.m.

T-1D Sour Oil Well Corrosion, Thursday a.m.

T-1D-1 Fundamentals of Corrosion Wednesday a.m.

T-1F Metallurgy, Tuesday a.m.

T-1G Sulfide Stress Corrosion Cracking, Wednesday p.m.

T-1H Oil String Casing Corrosion, Tuesday a.m.

T-1J Oil Field Structural Plastics, Thursday p.m.

T-1K Inhibitors for Oil & Gas Wells, Wednesday p.m.

T-2A Galvanic Anodes, Tuesday p.m.

T-2A-2 Ribbon Anodes, Tuesday a.m.

T-2B Anodes for Impressed Currents, Monday p.m.

T-2C Minimum Current Requirements, Monday a.m.

T-2D Standardization of Procedures for Measuring Pipe Coating Leakage Conductance, Monday p.m.

T-2E Internal Corrosion of Product Pipe Lines and Tanks, Tuesday p.m.

T-2F Internal Corrosion of Crude Oil Pipe Lines and Tanks, Monday a.m.

T-2G Coal Tar Coatings for Underground Use, Monday p.m.

T-2H Asphalt Type Pipe Coatings, Tuesday a.m.

T-2J Wrappers for Underground Pipe Line

T-2K Prefabricated Plastic Film for Pipe Line Coating, Monday a.m.

T-3A Corrosion Inhibitors, Wednesday, a.m.

T-3B Corrosion Products, Monday p.m.

T-3C Annual Losses Due to Corrosion, Monday p.m.

T-3D Instruments for Measuring Corrosion, Tuesday, a.m.

T-3D-1 Electrical Holiday Inspection of Coatings, Tuesday a.m.

T-3E Railroads, Wednesday a.m.

T-3E-1 Corrosion of Railroad Tank Cars, Wednesday a.m.

T-3E-2 Corrosion in Railroad Hopper Cars, Wednesday p.m.

T-3F Corrosion by High Purity Water, Wednesday p.m.

T-3G Cathodic Protection, Tuesday a.m.

T-3H Tanker Corrosion, Tuesday p.m.

T-4A Effects of Electrical Grounding on Corrosion, Wednesday a.m.

T-4B Corrosion of Cable Sheaths, Tuesday p.m.

T-4B-1 Lead and Other Metallic Sheaths, Tuesday a.m.

T-4B-2 Cathodic Protection, Tuesday a.m.

T-4B-3 Tests and Surveys, Tuesday p.m.

T-4B-4 Protection of Pipe Type Cables, Tuesday p.m.

T-4B-5 Non-Metallic Sheaths and Coatings, Tuesday p.m.

T-4B-6 Stray Current Electrolysis, Tuesday a.m.

T-4D Corrosion by Deicing Salts, Monday p.m.

T-4E Corrosion by Domestic Waters, Tuesday p.m.

T-4F Materials Selection for Corrosion Mitigation in the Utility Industry, Monday a.m.

T-4F-1 Water Meter Corrosion, Monday p.m.

T-5A Chemical Manufacturing Industry, Monday p.m.

T-5A-1 Sulfuric Acid, Monday p.m.

T-5A-3 Acetic Acid, Tuesday a.m.

T-5A-4 Chlorine, Monday p.m.

T-5A-5 Nitric Acid, Monday a.m.

T-5A-6 HF Corrosion, Monday a.m.

T-5B High Temperature Corrosion, Tuesday a.m.

T-5B-2 Sulfide Corrosion at High Temperatures and Pressures in the Petroleum Industry, Monday p.m., Friday a.m.

T-5D Plastic Materials of Construction, Tuesday a.m.

T-5E Stress Corrosion Cracking of Austenitic Stainless Steel, Thursday a.m.

T-6A Organic Coatings and Linings for Resistance to Chemical Corrosion, Monday a.m.

T-6B Protective Coatings for Resistance to Atmospheric Corrosion, Tuesday a.m.

T-6E Protective Coatings in Petroleum Production, Thursday a.m.

T-6G Surface Preparation for Organic Coatings, Thursday a.m.

T-6H Glass Linings and Vitreous Enamels, Wednesday a.m.

T-6K Corrosion Resistant Construction with Masonry and Allied Materials, Thursday a.m.

T-6R Protective Coatings Research, Monday p.m.

T-6C Protective Coatings for Resistance to Marine Corrosion, Wednesday a.m.

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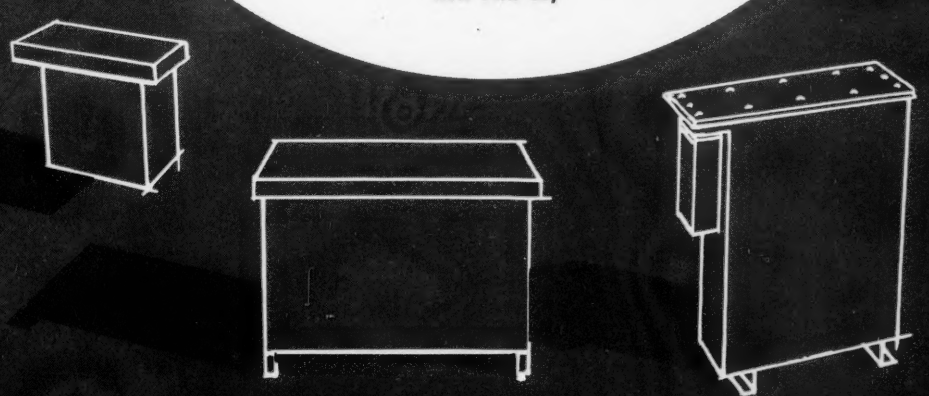

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Ten Technical—

(Continued From Page 58)

uring Pipe Coating Conductance. Publication 55-1, CORROSION Vol. 11, No. 2, 99t-102t (1955) February.

A general method and an attenuation method for measuring the electrical conductance of buried or submerged pipe lines are proposed. Definitions, test conditions and set up, instruments, procedures, calculations and methods of reporting results are covered. Appendix includes pertinent formulae, suggested forms for making reports.

(Unit Committee T-2D has completed a revision of this report. It is expected the revised version will be published within the next few months.)

Proposed Standardized Laboratory Procedure For Screening Corrosion Inhibitors For Use in Oil and Gas Wells, a Report of Technical Unit Committee T-1K on Inhibitors for Oil and Gas Wells. Publication 55-2, CORROSION Vol. 11, No. 3, 143t-146t (1955) March.

Need for a standard laboratory procedure for screening corrosion inhibitors for use in the oil and gas producing industry prior to field testing, was recognized by TP-1 (now T-1) in 1952. A paper presented at the 1953 NACE annual conference presented various methods of laboratory screening or evaluation being used. T-1K was organized for the purpose of developing a standardized test. As the result of the work of this committee, a standardized test has been devised and tested by various producing company laboratories. The test described in this report is a static oil and water immersion test using the weight loss of a steel coupon when under the influence of an inhibited system compared to its weight loss under an uninhibited system as a criteria of corrosion protection.

Some Corrosion Inhibitors—A Reference List, a Report of Technical Unit Committee T-3A on Corrosion Inhibitors. Publication 55-3, CORROSION, Vol. 11, No. 4, (1955) April.

Chemical and trade names, sources of supply, utility classes in which useful material with which effective and literature references for 68 inhibitors and classes of inhibitors are given. This list, consisting only of inhibitors for which literature references are available outside of manufacturers' literature, is conceded to be incomplete. Suggestions for additions and changes of presentation are solicited by the originating committee.

High Temperature Corrosion Data, a Compilation by Technical Unit Committee T-5B on High Temperature Corrosion. Publication 55-6, CORROSION, Vol. 11, No. 5, 241t-245t, (1955) May.

The behavior of 31 materials ranging from cast iron to lead, including a number of stainless steels and high alloys subjected to temperatures over 400 F is tabulated. Data are derived from Shell Development Company's Corrosion Data Survey (1948), among other sources. Corrosion rates are indicated as low, moderate or high versus specific temperatures. Additional data are solicited by the compiling committee.

Tenative Procedures for Preparing Tank Car Interiors for Lining, a Report by NACE Task Group T-3E-1 on Corrosion Control of Railroad Tank Cars CORROSION, Vol. 11, No. 6, 69-70 (1955) June.

Summary of Data on Use of Structural Plastic Products in Oil Production, a Status Report of NACE Technical Unit Committee T-1J on Oil Field Structural Plastics. CORROSION, Vol. 11, No. 6, 59-69 (1955) June.

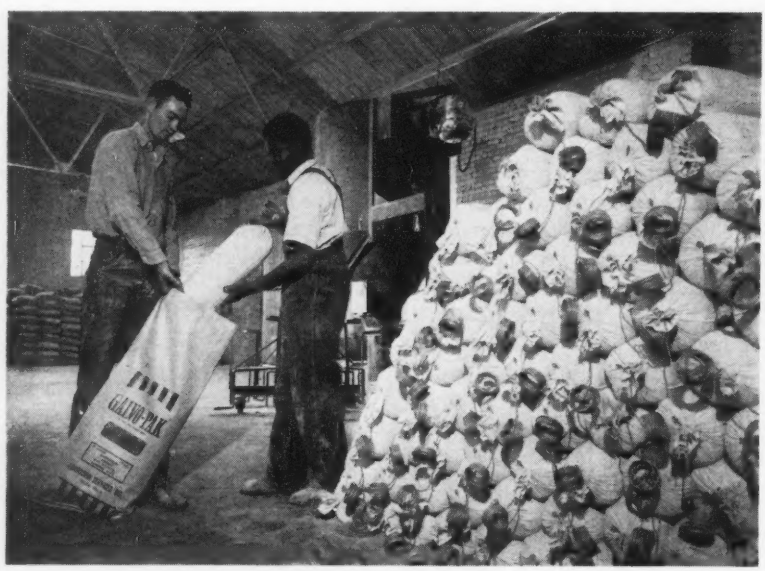
The report covers results of a questionnaire survey to determine experience to date. The most quantitative data developed by the survey were the strapping data on a 250 barrel glass-polyester and a like size glass-epoxy tank. After two years the glass-polyester tank was still creeping and subject to 0.152 percent volume change due to temperature difference between winter and summer. Not enough data are available on the glass-epoxy tank to determine creep rate, but it was noted that the volume change between winter and summer was about 0.10 percent.

Data covers two types of laminates in both constant load and fatigue type tests. Although tests were not complete at the time the data again indicated the large difference in short-term strengths in air and the long-term strengths in the service environment. In this case fatigue strengths seemed higher than stress rupture strengths, thereby indicating repeated tank fillings might not be a more severe service than a tank continually full.

Data on centrifugally cast pipe show that failures have occurred in 57 percent of the 21 reported installations. The data further indicate that the service of these materials is adversely affected by temperatures above atmospheric and pressures above 100 psi.

Reports to Technical Unit Committee T-1J on Oil Field Structural Plastics.

(Continued on Page 65)



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Ten Technical—

(Continued From Page 64)

Part 1. Long-Term Creep of Pipe Extruded From Tenite Butyrate Plastic. Part 2. Structural Behavior of Unplasticized Geon Polyvinyl Chloride. Publication 55-7, CORROSION, Vol. 11, No. 6, 277t-287t (1955) June.

Data are given of creep of extruded Tenite Butyrate pipe under internal pressure. Nine-foot lengths of pipe were maintained under different internal pressures. Data are given in 16 graphs showing individual creep data and four graphs summarizing each of four groups. Tables are given showing safe hoop stress values with corresponding tensile strength data.

Reports of an investigation of the effects of temperature on the physical properties of Geon non-plasticized polyvinyl chloride and the effect of temperature on short term tensile properties are given. The tests show that at relatively low stresses the deflection and rate of creep are directly proportional to applied stress. Above some stress limit varying between 2200 and 3000 psi deflection and rate of creep increase very much faster than stress. A minimum safety factor of 5 to 1 or 20 percent of ultimate tensile strength should be used.

Current Status of Corrosion Mitigation Knowledge on Sweet Oil Wells, a Report of Technical Unit Committee T-1C on Sweet Oil Well Corrosion. CORROSION, Vol. 11, No. 10, 61-63 (1955) October.

Corrosion in high pressure flowing oil wells is becoming increasingly common. Methods currently used to limit corrosion damage include coated tubing, inhibitors and alloy tubing, with tubing coated with baked on phenolics being favored most. Epoxies are being tested as a tubing coating.

Lack of success with weighted inhibitor sticks is reported, but some operators are pushing sticks to bottoms with wire tools. Bottom hole injection is being tried by some, but because of gelling of diluents in wells with high bottom hole temperatures, caution in selecting diluents is advised. Results on use of alloy tubing are inconclusive.

Laboratory work on duplicating the conditions noted with respect to sparingly soluble sulfate scales has met with considerable success. A technique for preparing artificial scale is reported. A theory covering the reason for the porosity of the scale is advanced.

In connection with corrosion believed water-dependent it is questioned whether circulation of a well after treatment down the annulus is beneficial. Some organic corrosion inhibitors are believed to accelerate corrosion at low concentrations.

Some Economic Data on Chemical Treatment of Gulf Coast Cooling Waters, a Report of the Recirculating Cooling Water Sub-Committee of NACE Task Group T-5C-1 on Corrosion by Cooling Waters, South Central Region. CORROSION, Vol. 11, No. 11, 61-63 (1955) November.

Based on the reported expenditures for inhibitors used in cooling towers of 16 Gulf Coast refineries and chemical plants, author estimates national cost of inhibitors in the chemical and refining industry to be $22,500,000.

Inhibitors are used in cooling water

(Continued on Page 66)

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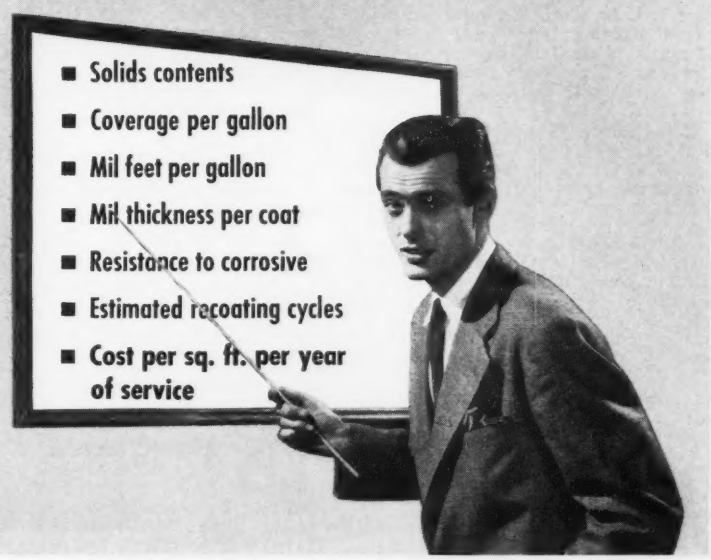

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Ten Technical—

(Continued From Page 65)

to regulate pH, reduce scale and corrosion and control algae. Materials used include sulfuric acid, caustic, sulfur, glucosates, sodium polyphosphate, sodium dichromate, chlorine and commercial products. Average cost of treating recirculating water on the Gulf Coast is estimated to be $2.21 per billion BTU's. Examples of costs in the three highest and three lowest expenditures reported are given.

Reports to Technical Unit Committee T-1J on Oilfield Structural Plastics. Part 1. Long Term Strengths of Reinforced Plastics Determined by Creep Strengths. Part 2. Microscopic Examination as a Test Method for Reinforced Plastic Pipe. CORROSION, Vol. 11, No. 11, 57-60 (1955) November.

Creep affects reinforced plastics and is a paramount factor in the determination of long term strength of structural reinforced plastics. It was found that the resins used are the central factor in the long term strength of the product. Creep studies of a given structure using various resins indicate that many resins have the same quick bursting strength but the workable stress loads for long term life vary greatly and in direct relation to comparative values of the resins.

Bond failure, elongation failure and low tensile strength failure are discussed briefly. A method of measuring creep involving the use of an extensometer is given.

Microscopic equipment having a magnification power of 20-120 diameters is suitable for distinguishing lack of adhesion in resin to glass from fracturing of resin where adhesion is still satisfactory. Reflected light when shown at 30-40 degrees to the surface of the sample and at right angles to the direction of glass fibers is useful in tests. Photographs are useful to a certain extent but the sample can be examined much better through a microscope with the naked eye.

Reports completed in 1955 and published in the January issue of CORROSION were: **Final Report on Four Annual Anode Inspections,** a Report of Technical Unit Committee T-2B on Anodes for Impressed Current. Publication 56-1, CORROSION, Vol. 12, No. 1, 63-74 (1956) January.

Four test ground beds were installed so that comparative data could be obtained concerning the performance of steel anodes in natural soil, carbon and graphite anodes in natural soil, carbon and graphite anodes in carbonaceous-backfill and steel anodes in carbonaceous backfill. Representative anodes were inspected at one year intervals with the final inspection coming four years after the beds were set up.

Of the anode types tested it was found that graphite anodes in a carbonaceous backfill gave the best results. Recommendations were made concerning the installation of anodes, the selection of ground bed sites and the use of various backfills.

Progress Report of Task Group T-4F-1 on Water Meter Corrosion. CORROSION, Vol. 12, No. 1, 77-80 (1956) January.

Susceptibility of water meters to corrosion is discussed with particular attention to the manner in which corrosion affects the operation of the individual parts. Case studies are given with accompanying illustrations. Other topics discussed include the economic aspects of water meter corrosion, the nature of the corrosion problem and factors contributing to corrosion. Suggestions are made regarding the type of research to be conducted in future investigations.

Tentative Recommended Specifications and Practices for Coal Tar Coatings for Underground Use, a Report of Technical Unit Committee T-2G on Coal Tar Coatings for Underground Use. CORROSION, Vol. 12, No. 1, 75-76 (1956) January.

Recommendations are given for practices to be adopted in the underground use of coal tar coatings. Topics discussed include coating requirements, long term performance, coal tar primer, coal tar enamels and application of coal tar coatings to pipe.

Reports completed in 1955 to be published in the next four issues of CORROSION are:

Field Practices for Controlling Water-Dependent Sweet-Oil Well Corrosion, a Report by Technical Unit Committee T-1C on Sweet-Oil Well Corrosion. Compiled by Task Group T-1C-1 on Field Practices.

The report presents a consensus of the oil producing industry's field practices for controlling corrosion in water-dependent sweet-oil wells. It covers practices by operators in over 676 fields and 29,187 wells. Limits are given for the various methods of classifying wells according to corrosiveness. Methods are given for equipping wells including new equipment used and special techniques recently developed. Special materials used and chemical treatments employed to combat corrosion are described and discussed. Methods are given for determining the effectiveness of chemical treatment.

Status Report of Technical Unit Committee T-1J on Oil Field Structural Plastics.

Long term strength of cellulose acetate butyrate is discussed. The strength of the material had been reported previously to be near 800 psi at about 100 F. Recently another investigator found the value to be around 400 psi by a similar test. Reasons for the difference are discussed and explained by the company making the first report.

A report on service experience of plastic tanks is given. This supplements a report on this subject published in 1955. Cracking type failure is believed to result from eccentric loading that come from filling and emptying the tank. The cracks generate from irregularities or wrinkles in the glass. If the theory is true, cracking type failure can occur with tanks fabricated from any resin system and probably can be eliminated only by careful glass handling and control by the tank fabricator.

A Bibliography of Corrosion by Chlorine. A Report of NACE Task Group T-5A-4 on Chlorine.

The bibliography contains 86 abstracts of papers on corrosion by chlorine. It is indexed by materials and coded by the NACE Abstract Code.

Third Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths entitled "Examples of Concentration Cell Corrosion on Lead Cable Sheaths by Task Group T-4B-1 on Corrosion of Lead and other Metallic Sheaths.

Conditions that will produce concentration cells are described. Corrosion action of the cells is discussed. An illustrated example of attack on lead cable sheath by differential aeration cell action is given. Another illustrated example of unusual corrosion considered as a type of concentration cell is given. In the communications field a greater variety of corrosion by concentration cells is recognized than in other fields of corrosion engineering. It occurs at innumerable places where metal is in contact both with water and air. Crevice corrosion, pitting and corrosion under scale are almost invariably produced by differential aeration cells which the report shows to be concentration cell action.

Reports nearing completion:

A Report on Rigid Vinyl Coatings for Resistance to Chemical Corrosion by Task Group T-6A-2 on Vinyl Coatings.

(Continued on Page 67)

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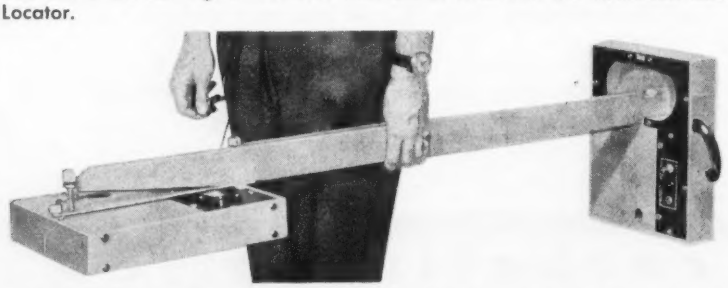

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Ten Technical—

(Continued From Page 66)

A Report on Chlorinated Rubber Coatings for Resistance to Chemical Corrosion by Technical Unit Committee T-6A on Organic Coatings and Linings for Resistance to Chemical Corrosion.

A Report on Epoxy Coatings for Resistance to Chemical Corrosion by Task Group T-6A-11 on Epoxy Coatings.

A Bibliography of Corrosion Products, a Report of Technical Unit Committee T-3B on Corrosion Products.

Includes 14 abstracts on the corrosion products of Zirconium; 51 abstracts on corrosion products of tin and tin alloys; 9 abstracts and 35 references on corrosion products of titanium; 57 abstracts on corrosion products of stainless steels; 129 abstracts on corrosion products of iron and steel; 10 abstracts on corrosion products of copper and copper alloys; 13 abstracts on corrosion products of zinc; 35 abstracts on corrosion products of silver; 23 abstracts on corrosion products of lead; 49 abstracts on corrosion products of aluminum; and additional abstracts on corrosion products of magnesium, chromium and nickel.

Fourth Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths entitled Bonding and Grounding Practices for Corrosion Mitigation in the Utilities Industry by Task Group T-4B-6 on Stray Current Electrolysis.

Fifth Interim Report of Technical Unit Committee T-4B on Corrosion of Cable Sheaths entitled Cathodic Protection of Cable Sheaths by Task Group T-4B-2 on Cathodic Protection.

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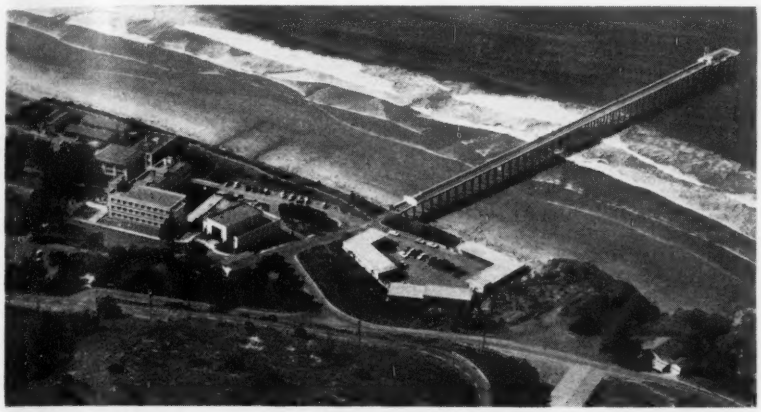
NACE NEWS



SCRIPPS INSTITUTION OF OCEANOGRAPHY and pier at LaJolla, Cal. where the April 18-20 Conference on Marine Corrosion and Fouling Problems will be held. It is sponsored by the Institute of Marine Resources and the Department of Engineering, University of California with the cooperation of San Diego Section and Western Region NACE. (See Page 102, January 1956 issue of CORROSION for more information.)

Fair Is Speaker at Kanawha Meeting

Approximately 50 members and guests attended the November 17 meeting of Kanawha Valley Section and heard W. F. Fair, Jr., Koppers Co., present a paper on Protective Coatings for Underground Structures. Following Dr. Fair's talk Van de Linder was appointed as a second representative from the Kanawha Valley Section NACE to the Kanawha Valley Technical Council.

Conrad Wiegers, Allied Services, Inc., chairman of the nominating committee named the following for section officers in 1956: J. M. Bates, Carbide and Carbon Chemicals, chairman; George W. Klohr, E. I. du Pont de Nemours & Co., Ltd., vice-chairman; Frederick W. Lloyd, United Fuel Gas Co., treasurer; George F. Walther, Westvaco Chemical Div., Food Machinery and Chem. Corp., secretary.

At a meeting scheduled January 19 Wayne W. Binger was due to discuss Corrosion Behavior of Aluminum Alloys in Different Chemical Environments.

Truchelut Is Named to Head Miami Section

H. L. Truchelut, Southern Bell Telephone and Telegraph Co., Miami, has been elected chairman of Miami Section for 1956. Also elected were N. O. Boutzilo, People's Water and Gas Co., North Miami, vice-chairman and H. B. Sasman, Sasman Engineering Co., Miami, secretary-treasurer.

Philadelphia Section's New Officers Are Announced

At the December 9 meeting of Philadelphia Section the following persons were reported elected as officers for 1956: T. F. Degnan, 701 W. 22nd St., Wilmington, Del., chairman; S. F. Spencer, Keystone Shipping Company, Philadelphia, vice-chairman and M. L. Rosenfeldt, Water Service Labs., Inc., Philadelphia, secretary-treasurer.

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Corrosion is indexed annually by Engineering Index.

Coatings and Cathodic Protection Discussion Scheduled at Houston

Coatings and Cathodic Protection is the title of the technical paper for the February 14 meeting of the Houston Section, National Association of Corrosion Engineers. C. G. Munger, Vice President of Amercoat Corp., South Gate, Calif. will be the speaker.

Mr. Munger will discuss specific types of coatings and their behavior in the presence of electrical current flow, especially in regard to potentials which coatings can tolerate without blistering or being otherwise damaged. The section meeting will be held at John's Restaurant, 9350 S. Main St.

At the Jan. 10 meeting, section members heard John Watts, technical representative for Internal Pipeline Maintenance Co., Odessa, Texas speak on The Evolution of In-Place Coating Techniques.

The critical phase of in-place coating application is surface preparation, Mr. Watts said. Development of new and better equipment and techniques have made plastic coating in place successful, he said. A high solids epoxy coating which will stick to the pipe up to 10 mils thick in one application and not flow to the bottom part of the pipe is now in use, he said. New methods of cleaning have been developed. Capacity of air compressors used to blow out lines and drive swabs through the pipe have increased from small compressors approximating 600 cubic feet of air a minute to 2400 cubic feet of air a minute. Two way radio communication and the use of radioactive devices to determine internal coating conditions and for other uses were mentioned by Mr. Watts.

Humberto Lobo, Jr., Fabricas Protexa, S. A., Monterrey, N. L., Mexico, announced the corrosion short course sponsored by NACE and Instituto Tecnologico y de Estudios Superiores de Monterrey, scheduled for Feb. 1-3 in Monterrey, Mexico.

Alvan Richey, Cathodic Protection Service, Section Chairman said H. C. Morgan, Gulf Oil Co., who has been entertainment chairman for the section has been transferred to Morgan City, La.

Nominations for the Whitney and Speller Awards

The Willis Rodney Whitney Award is given in recognition of public contributions to the science of corrosion. A contribution to science is defined as the development of new information or the development of a more satisfactory theory which contributes to a more fundamental understanding of corrosion phenomena.

The Frank Newman Speller Award is given in recognition of public contributions to corrosion engineering. A contribution to engineering is defined as the development or improvement of a method, apparatus or material by which the control of corrosion is facilitated or made less costly.

Nominations may be made by local sections or may be proposed directly to the Chairman of a Region by individual members up to June 1, 1956. In any case, nominations should be accompanied by an appropriate statement of the basis of the proposal.

A copy of the Procedure in the Selection of Persons to Receive these awards will appear in the March issue of CORROSION.

NOTICE ON PAYMENT OF 1956 NACE DUES

Invoices for 1956 membership dues have been sent to all Active and Junior NACE members. These dues are payable January 1, 1956. The NACE by-laws state that no member with dues in arrears for three months shall receive the publications of the association until such dues are paid.

• Accordingly the names of Active and Junior members whose 1956 dues have not been received by March 30, 1956 will be removed from the mailing list to receive CORROSION. No mailings of CORROSION will be made to delinquent members until dues are paid.

Bernard A. Kosteck

Bernard A. Kosteck, a design engineer for heat exchangers and pressure vessels for Killebrew Engineering Corp., St. Louis died December 19. He formerly was a member of the National Association of Corrosion Engineers.

Titanium Volume Is Up

Dollar value of titanium mill products for 1955 is estimated at $60 millions, with sales of sponge metals accounting for an additional $30 millions. An estimated 1900 tons of mill products were produced, according to T. W. Lippert, Titanium Metals Corp. of America, New York.

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PHILADELPHIA SECTION'S Christmas party featured an accordionist, left, who played during the evening. Center is James Madigan, Rohm and Haas Company, who helped secure door prizes, some of which are seen on the table and right is George Kern, Gates Engineering Company, Wilmington, Del., chairman of the Fellowship Committee.

Philadelphia Section Has 56 at December Meeting

Approximately fifty-six members and guests attended the December 9 meeting of the Philadelphia section at the Poor Richard Club, Philadelphia.

Meetings of the section had been scheduled for February 10, March 11, in addition the October 1956 meeting of the Northeast Region which will headquarter in the Drake Hotel, Philadelphia. Subject of the February 10 meeting is Coatings, and a film entitled "The Story of Colonel Drake," which deals with the discovery of oil at Titusville, is also scheduled to be shown.

The technical phase of the December 9 meeting consisted of showing a sound color movie entitled "Mining of Nickel," released by the International Nickel Company, Inc. The film detailed the physical and engineering aspects of the search for nickel ore, location of the strike, creation of the mine and methods of extracting ore from the earth. The five principal methods of removing the ore are: Square set method, cut and fill, shrinkage, open pit, and caving mining.

Internal Coatings Is Topic At Permian Basin Session

William T. Theis of the Internal Pipeline Maintenance Company, Odessa, Texas spoke on "Reasons for and Methods of Internally Coating Pipe Lines in Place" at the December 12th meeting of the Permian Basin Section before approximately 32 members and guests.

Section officers for 1956 introduced were as follows: John V. Gannon, The Texas Company, chairman; Harold S. Winston, Gulf Oil Corp., first vice-chairman; W. H. (Jack) Gray, Sivalls Tanks, Inc., second vice-chairman; Roscoe Jarmon, Cardinal Chemical Co., secretary-treasurer; John C. Watts, Jr., Internal Pipeline Maintenance Co., trustee.

•

Indexes to Corrosion's Technical Section, Technical Committee Activities Section and Corrosion Abstract Section are published annually in the December issue.

NACE MEETINGS CALENDAR

Feb.

2 Pittsburgh Section. Mellon Institute.

6 North Texas Section. At Dallas, Cathodic Protection Ground Beds by J. L. Pool, Magnolia Pipe Line Co.

7 Schenectady-Albany-Troy Section. R. C. Ulmer, Combustion Engineering, Inc., "General Corrosion Problems in Industrial and Marine Boiler Operation."

8 Greater Boston Section. Hotel Beaconsfield. Corrosion of Light Metals, R. R. Cope, Aluminum Company of America.

14 Houston Section. John's Restaurant. C. G. Munger, Amercoat Corp., South Gate, Cal., "Use of Coatings in Industry."

15 Genesee Valley Section. Joint meeting with American Institute of Chemical Engineers. Subject: Kel-F Coatings.

21 Chicago Section. Chicago Engineers Club. M. G. Fontana, Ohio State University, "Various Approaches to Corrosion Problems."

21 Cleveland Section. Hotel Manger. Corrosion in Military Installations. Col. Lindsay M. Applegate, U. S. Army Corps of Engineers, Omaha.

23 Sabine-Neches Section. Orange, Texas. Corrosion Problems in High Speed Rotary Compressor, A. D. Hardgroder, Mathieson Chemical Corp., Lake Charles, La.

28 Southwestern Ohio Section. Shuller's Restaurant, Reading, Ohio. Causes of Corrosion, Part 2. Wm. Spurgeon, General Electric Co.

NATIONAL, REGIONAL MEETINGS and SHORT COURSES

Mar. 12-16—NACE 12th Annual Conference and Exhibition, Statler Hotel, New York City.

Oct. 23-26—South Central Region, Gunter Hotel, San Antonio, Texas.

1957

Mar. 11-15—NACE Annual Conference, Kiel Auditorium, St. Louis, Missouri.

1958

Mar. 17-21—NACE Annual Conference, Civic Auditorium, San Francisco, California.

1959

NACE Annual Conference, Sherman Hotel, Chicago, Illinois.

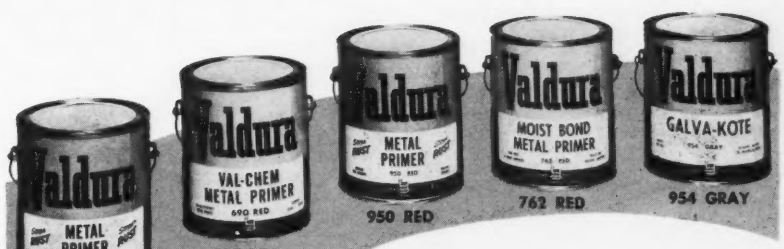
SHORT COURSES

1956

Feb. 15-17—Tulsa Section Seventh Annual Corrosion Short Course for Pipeliners, Mayo Hotel, Tulsa, Okla.

Apr. 3-5—Corrosion Control Short Course, University of Oklahoma.

Apr. 18-20—Conference on Marine Corrosion and Fouling Problems, Scripps Institution of Oceanography, LaJolla, Cal.



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Central Oklahoma Section Names Officers for 1956

At the December 27 meeting of Central Oklahoma Section the following officers were elected for 1956: Loyd Goodson, Oklahoma Natural Gas Co., chairman; E. G. Stevens, Dowell, Inc., vice-chairman; Richard V. James, University of Oklahoma, secretary-treasurer.

Dan Carpenter, W. H. Meigs, and R. V. James, were appointed a committee to arrange a new meeting place.

Plans for the 1957 South Central Region meeting also were discussed and the following persons were elected officers to handle arrangements for this meeting: General chairman, Dan H. Carpenter; W. H. Meigs, assistant; finance chairman, Frank B. Burns, Kerr-McGee Oil Industries, Inc.; entertainment chairman, Earl Shaffer; publicity chairman, E. G. Stevens, Dowell, Inc.; A. L. Minnick, Oklahoma Natural Gas Co., assistant; registration and housing, M. L. Steffens, Oklahoma Natural Gas Co.; printing, Loyd Goodson, Oklahoma Natural Gas Co.; properties, R. D. McDonald, Oklahoma Natural Gas Co., chairman, M. E. Pourchot, Central Plastics Company, assistant.

Two-Day Houston Section Course Held Jan. 19-20

First day orientation on fundamentals at Houston Section's short course on corrosion held January 19-20 at University of Houston was accomplished with the International Nickel Company's motion picture "Corrosion In Action." Maurice A. Riordan, Rio Engineering Co., Houston, was in charge of the fundamentals phase of the program.

Other phases of the instruction were handled as follows: External corrosion, L. G. Sharpe, Napko Paint and Varnish Co.; fundamentals of cathodic protection, Marshal M. Parker, Cormit Engineering Co.; internal corrosion, Lyle R. Sheppard, Shell Pipe Line Corp.; system design and instruments, O. W. Wade, Transcontinental Gas Pipe Line Co.

C. L. Woody, United Gas Corp., is general chairman; J. H. Spracklen, Transcontinental Gas Pipe Line Corp., arrangements chairman; W. A. Wood, Jr., Products Research Service, program chairman; Loyd Nelson, Shell Pipe Line Corp., registration chairman; John E. Loeffler, Thornhill-Craver Co., finance chairman and W. H. Waring, Johns-Manville Sales Corp., printing and publicity chairman.

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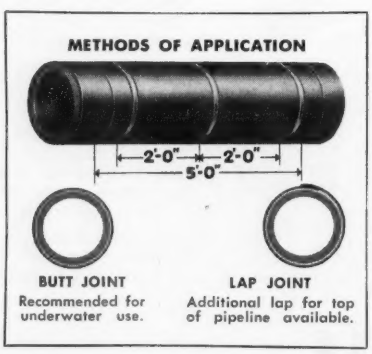

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Monterrey Short Course to Be Held February 1-3

The complete program for the February 1-3 Short Course on Corrosion at Instituto Tecnologico y de Estudios Superiorer de Monterrey, Monterrey, Mexico has ben announced as follows:

February 1

Introduction, Ing. Eliot Camarena, director of the Engineering Schools of ITESM.

Corrosion and Cathodic Protection Simplified, G. R. Olson, United Gas Pipe Line Co., Shreveport, La.

Protective Coatings, W. F. Fair, Jr., Koppers Co., Inc., Pittsburgh.

Insulated Couplings—When Where and How to Insulate, R. B. Bender, Plastic Engineering and Sales Corp., Fort Worth.

Plastic Tapes—A New Development in Pipe Line Coatings, R. B. Bender, Plastic Engineering and Sales Corp., Fort Worth.

February 2

Corrosion Control Instruments, W. H. Stewart, Sun Pipe Line Company, Beaumont, Texas.

Galvanic Anodes, E. P. Doremus, Cathodic Protection Service, Houston.

Protecting Multiple Pipe Lines, Derk Holsteyn, Shell Oil Co., Houston.

Plant Protection Problems, John W. Jenninga, Compania Carbonifera de Sabinas, S. A. Rosita, Coahuila, Mexico.

February 3

Protecting a City's Gas Distribution System, Sidney E. Trouard, New Orleans Public Service Co., New Orleans.

Organization for Corrosion Control, K. D. Wahlquist, Southern Union Gas Company, Dallas.

Brief History of Protective Pipe Coatings in the United States, Thomas F. P. Kelly, Mavor-Kelly Company, Houston.

Protective Coatings in Mexico, Humberto Lobo, Jr. Fabricas Protexa, S. A., Monterrey, N. L., Mexico.

Closing remarks, Ing. Victor Bravo Ahuja, Rector, Institute of Technology, Monterrey.

The National Association of Corrosion Engineers is cooperating in presenting the course.

Pipe Line Corrosion Is Toronto Symposium's Topic

Toronto Section's February 16-17 Symposium on Pipe Line Corrosion to be held at the Royal York Hotel, Toronto will have the following program:

History and Future of Pipelining in Canada by T. S. Johnston, president Interprovincial Pipe Line Co., Toronto.

Planning a Pipeline by Clark Root, Divisional Manager, Canadian Bechtel Ltd., Toronto.

Corrosion Survey and Planning by Gordon Russell, vice-president, Mid-Canada Contractors, Ltd., Toronto.

Pipe Line Contracting by R. Banister, president, Banister Construction Ltd., Edmonton. Coating Practices by Alex McClure, Western Representative, Koppers Products Ltd., Edmonton.

Cathodic Protection by H. A. Webster, corrosion engineer, Corrosion Services, Ltd., Toronto.

Corrosion Inspection Practices by F. Farrer, corrosion engineer, Trans-Northern Pipe Line Company, Toronto.

Corrosion Testing Equipment by A. B. Murdison, Electrical and Instrument Engineer, Imperial Oil Co., Pipe Line Division, Toronto.

What Management Expects from a Corrosion Engineer by W. L. Dutton, Technical Consultant, United Gas and Fuel Co., Hamilton.

Also scheduled for presentation is a film produced by Consumer's Gas Company, Toronto with W. Landon, assistant superintendent of construction and maintenance as commentator. A panel discussion for presentation of individual questions will follow the formal papers.

Lance Rumble, general manager, GMC Toronto Truck Retail Branch will be guest speaker at a dinner February 16.

Aaron B. Bagsar

Aaron B. Bagsar, chief metallurgical engineer for Sun Oil Company, died at his home, Drexel Hill, Pa., October 7. He was 58.

He had been connected with the company's Marcus Hook refinery since 1932.

A native of Turkey, he came to the United States at 17 years of age after his family had been wiped out in the First World War. He received a BS degree from University of California in 1924 and a MS at the University of Idaho in 1925. A year later he received a PhD from Columbia University.

He served on a special materials subcommittee for the American Bureau of Shipping and was a member of ASTM, The Electrochemical Society, ASM, AWS, API, NACE and the AIME.

Southeast Region to Meet

Southeast Region's spring 1956 meeting will be held May 4-5 at Atlanta, Ga.

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By far the greater part of all technical material published in Corrosion is found in no other periodical. Two of every three editorial pages contain material with reference value.

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Technical material published in Corrosion is abstracted in the biennial Bibliographic Surveys of Corrosion published by NACE.

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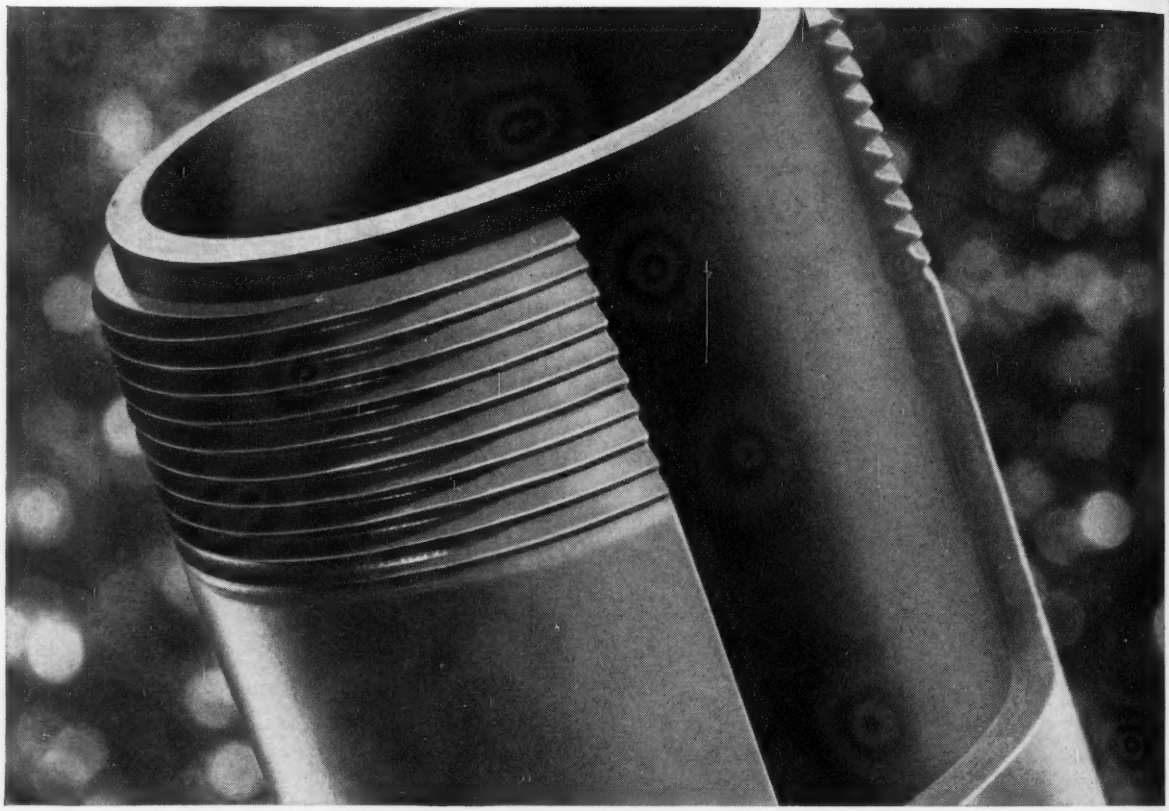

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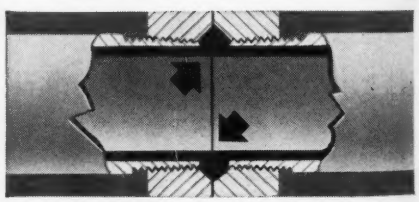

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14 Symposia, 3 Discussion Sessions Are Set

Gas Turbine Paper Qualified E. L. Simons For Junior Award

A paper on the effects of sodium sulfate in gas turbines, concerned with the corrosion of metals attacked by deposits formed by residual fuels was judged most meritorious of those published in 1955 in CORROSION by an author under 35 years of age. This paper, authored by Edward L. Simons, George V. Browning and H. A. Liebhafsky, "Sodium Sulfate in Gas Turbines," was published beginning on page 505t of the December, 1955 issue. All authors are with the General Electric Company.

Simons

The author selected to receive the 1955 NACE Junior Award, Edward L. Simons, is a research associate in the Analytical Chemistry Unit, General Electric Research Laboratory, Schenectady, N. Y. He has been active in NACE affairs, having been the 1955 chairman of Schenectady-Albany-Troy Section.

His interests technically include inorganic analysis, phase equilibria and corrosion phenomena. He holds a PhD in chemistry from New York University in 1945 and after two years on the Manhattan Project, was an assistant professor at Rutgers University.

He is a member of NACE Unit Committee T-3B on Corrosion Products.

Advance Program, Hotel Registration Cards Mailed

Copies of the advance program for the 1956 Conference in New York have been mailed to NACE members. The advance program, correct as of about January 15, plus a card for use of those who want to register in advance and a hotel reservations card were mailed from Central Office during the last week in January. Members who did not receive the mailing and who need the information may get a copy on request.

Banquet Events Follow Usual Pattern at N. Y.

Presentation of the NACE Awards and the Junior Award will be made during the annual banquet Wednesday, March 14 in the Penn Top Room of Hotel Statler, New York. Also scheduled is entertainment to follow the program and dinner. An orchestra will play during the evening.

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More than 230 authors contributed to the Technical Section in Volume 11, Corrosion.

Only a Few Booths Left In Corrosion Show

Only a few booths remain unsold in the 1956 Corrosion Show which will be held concurrently with the 1956 NACE Conference at Hotel Statler, New York. Fifteen more companies have contracted for space since the report published in January CORROSION. They are:

American Coating Supply Co., Brance Krachy Company, Clementina Limited, General Alloys Company, Harco Corporation, Inertol Company, Inc., Insul-Mastic Corporation of America, National Lead Company, Niphos Process Sales Corporation, Remco Manufacturing Company, Inc., Shell Chemical Company, Shell Oil Company, The Speeflow Company, Tinker & Rasor, Tretolite Company (A Div. of Petrolite Corp.)

TECHNICAL PROGRAM

MONDAY—March 12
- Committee meetings all day.

TUESDAY—March 13
- Business Meeting
- Corrosion Principles Symposium
- Chemical Inhibitor Symposium
- Refinery Industry Symposium (Part 1)
- Oil and Gas Production Symposium
- High Purity Water Symposium
- Educational Lecture

WEDNESDAY—March 14
- Chemical Industry Symposium (Part 1)
- General Pipe Line Symposium
- Steel Metallurgy and Corrosion
- Chemical Industry Symposium (Part 2)
- Power and Communications Symposium
- Pipe Line Group Discussions
- Educational Lecture

THURSDAY—March 15
- Cathodic Protection Symposium
- Plastics Symposium
- Refinery Industry Symposium (Part 2)
- Elevated Temperature Symposium
- Protective Coatings Symposium
- Worldwide Developments in Corrosion
- Educational Lecture

FRIDAY—March 16
- General Corrosion Round Table
- Pipe Line Underground Round Table

Fellowship Hour to Be Held in Penn Top Room

The Fellowship Hour of the 12th Annual NACE Conference will be held in the Penn Top Room of the Hotel Statler on Tuesday, March 13, after the close of the technical sessions.

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Indexes to Corrosion's Technical Section, Technical Committee Activities Section and Corrosion Abstract Section are published annually in the December issue.

Technical Program to Be Most Extensive In NACE History

With fourteen symposia and three discussion sessions scheduled during the technical program at the NACE Twelfth Annual Conference and Corrosion Show March 12-16 in New York there is substantial assurance a wide variety of information will be available. The number of symposia has necessitated for the first time in NACE history, scheduling triple simultaneous sessions.

In addition to the technical program, there will be meetings of more than 60 of the NACE technical committees, of the standing committees and the usual social events, including the annual banquet at which the NACE Awards and the annual Junior Author's Award will be presented.

Among the other innovations there will be for the first time a symposium of papers of authors from outside North America. This presentation will emphasize the international aspects of corrosion mitigation and underline the influence NACE has had in encouraging the organization of associations for corrosion control abroad.

The schedule of events has been arranged to permit registrants to visit the Corrosion Show both before and after technical sessions and during the midday recess. The Corrosion Show will include the usual broad distribution of products and services, including many newcomers at NACE exhibitions.

Advance registration procedure has been arranged. Notices will be sent NACE members sufficiently far in advance for them to send in their requests. Their registration cards, badges, banquet tickets and other items will then be prepared in a package for distribution when they arrive at Hotel Statler. There will be a separate table for preregistrants and it is expected this will materially speed the procedure.

Advance Registration Forms Will Be Mailed

Plans have been completed for advance registration for the 12th Annual Conference and Corrosion Show. Members of NACE will receive by mail a form which will permit their indicating their needs and these will be used to prepare packets.

When a registrant who has preregistered applies at the pre-registration desk at Hotel Statler, he will be given his packet, which will include the things requested. No money will be sent in with advance registrations.

Members are encouraged to preregister so that the usual waiting at the desks can be minimized.

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By far the greater part of all technical material published in Corrosion is found in no other periodical. Two of every three editorial pages contain material with reference value.

Fretting, Fatigue Corrosion Principles Topics

Fundamentals of Complex Reactions Will Be Discussed

The recurring necessity to emphasize the fundamental aspects of corrosion reactions is recognized in the Corrosion Principles Symposium scheduled to begin at 10:15 am Tuesday, March 13. This symposium follows immediately after the annual business meeting and is concurrent with the Chemical Inhibitor Symposium.

R. B. Hoxeng, United States Steel Corp., Applied Research Laboratory, Monroeville, Pa. and W. A. Luce, The Duriron Company, Dayton, Ohio are chairmen.

Papers scheduled to be presented concern fretting and fatigue. Abstracts follow:

Fretting Corrosion by H. H. Uhlig, Massachusetts Institute of Technology, Cambridge.

Fretting corrosion occurs whenever a metal in contact with another metal or non-metal is subject to relative slip. Damage of this kind presently worries the mechanical engineer who designs or operates vibrating machinery and structures and the problem is one which the corrosion engineer should know more about. Examples of fretting damage to industrial equipment are reviewed, together with fundamental factors entering the extent of damage such as environment, load, magnitude of slip and frequency of vibration. The mechanism of damage is discussed and remedial measures are outlined based on practical experience and on suggestions derived from the proposed mechanism.

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Corrosion Fatigue by I. Cornet, University of California, Berkeley.

Metals subjected to cyclic tensile stress in a corrosive environment may suffer an attack known as corrosion fatigue. The part subjected to alternating stress shows numerous deep sharp pits; from many of these pits cracks emanate and failure originates at one of these cracks.

Corrosion fatigue damage is more common than is generally appreciated. It results in failures of components under cyclic stress at a fraction of their conservative design strength and time, failures which are not anticipated by conventional design data on fatigue or corrosion alone. For example, in carbon and low alloy steels the improvement in mechanical properties obtained by cold working or heat treatment is of little or no benefit in resisting the ravages of corrosion fatigue.

Corrosion fatigue can be eliminated by suitable selection of materials, but this may not be economic. In a susceptible material, corrosion fatigue may be controlled by reducing stresses through appropriate design. Cathodic protection can be effective and in many cases the use of an inihbitor has proved to be economical in halting corrosion fatigue.

•

A 10-Year Index to the material in Corrosion Technical Section 1945-54 inclusive will be published soon.

Cornet

Hoxeng

Luce

Uhlig

ABOUT the AUTHORS

HERBERT H. UHLIG—Presently professor of metallurgy in charge of the MIT Corrosion Laboratory, he is editor of the Corrosion Handbook and author of numerous technical papers on corrosion, electrochemistry and metallurgy. Currently president of The Electrochemical Society, he helped found and is a member of the newly organized Corrosion Research Council of the Engineering Foundation. He is a member of the advisory committee of the Prevention of Deterioration Center of the National Research Council, a member of the American Academy of Arts and Sciences and of several technical societies here and abroad. He has been in corrosion research for the past 20 years and in 1951 received the NACE Willis Rodney Whitney award. His interests are mainly on studies of corrosion mechanisms and control.

ISRAEL CORNET—Associate Professor of process engineering at the University of California at Berkeley. He has been a member of the NACE Awards committee and is active in the educational work of Western Region NACE, helping organize and conduct short courses and conferences on corrosion in California. He teaches corrosion at the university, is active in research, particularly on corrosion fatigue and stress corrosion.

NORMAN HACKERMAN—Chairman of the chemistry department of the University of Texas, he has been active in NACE affairs for many years. Author of many technical papers on corrosion processes, he is head of the NACE Education Committee and participates in the administrative and technical committee activities of the association. He has a PhD from Johns-Hopkins University (1935).

HARRY R. COPSON—Dr. Copson, head of the Corrosion Section of the Research Laboratory, The International Nickel Co., Inc., Bayonne, N. J., has been chairman of the Corrosion Division of The Electrochemical Society and general chairman of the society's 1953 New York meeting. In 1949 he was chairman of the AAAS Gordon Research Conference on Corrosion and in 1946 was awarded the Dudley Medal of the ASTM. Active on many corrosion committees, author of many papers, he has a BS from University of Massachusetts (1929) and PhD in physical chemistry from Yale (1932). He has been active in corrosion research since 1934.

Hackerman

Copson

CORROSION PRINCIPLES

Fretting Corrosion by H. H. Uhlig, Massachusetts Institute of Technology, Cambridge, Massachusetts.

Corrosion Fatigue by Israel Cornet, University of California, Berkeley, Calif.

EDUCATIONAL LECTURES

A Fundamental Approach to the Mechanisms of Corrosion Inhibition by Norman Hackerman, University of Texas, Austin, Texas.

The Relation of Thin Films to Corrosion by T. N. Rhodin, E. I. DuPont de Nemours and Company, Wilmington, Delaware.

Effects of Velocity on Corrosion by H. R. Copson, The International Nickel Co., Inc., Bayonne, N. J.

Three Educational Lectures to Be Given

Three educational lectures will be given during the 1955 NACE 12th Annual Conference. These lectures, which have attracted overflow crowds at every session since they were started some years ago, will be held beginning at 4:30 pm on Monday, Tuesday and Wednesday, March 13, 14 and 15.

F. H. Beck, Ohio State University, Columbus and J. J. Harwood, Office of Naval Research, Washington, D.C. are chairmen.

Available abstracts follow:

A Fundamental Approach to the Mechanisms of Corrosion Inhibition by Norman Hackerman, University of Texas, Austin.

If the definition of corrosion inhibition as the treatment of the metal surface in place by addition of a chemical to the environment is accepted, it follows that inhibition is always preceded by adsorption. Adsorbed material may be held to the solid surface by purely physical adsorption or it may be attached by bonds which are more nearly like those which hold together the component particles of molecules. This is chemisorption. With either type of attachment the inhibitor provides a more or less continuous barrier between the two reacting phases. Such separation is one of the three general ways of retarding corrosion or any heterogeneous reaction. The other two are: Reduction in reactivity of the environment and reduction in reactivity of the metal. The latter kind of function can be provided by inhibitors also but in such cases chemisorption is required.

Either kind as well as extent of sorption, can be related to the structure of the adsorbing particle. Hence the ef-

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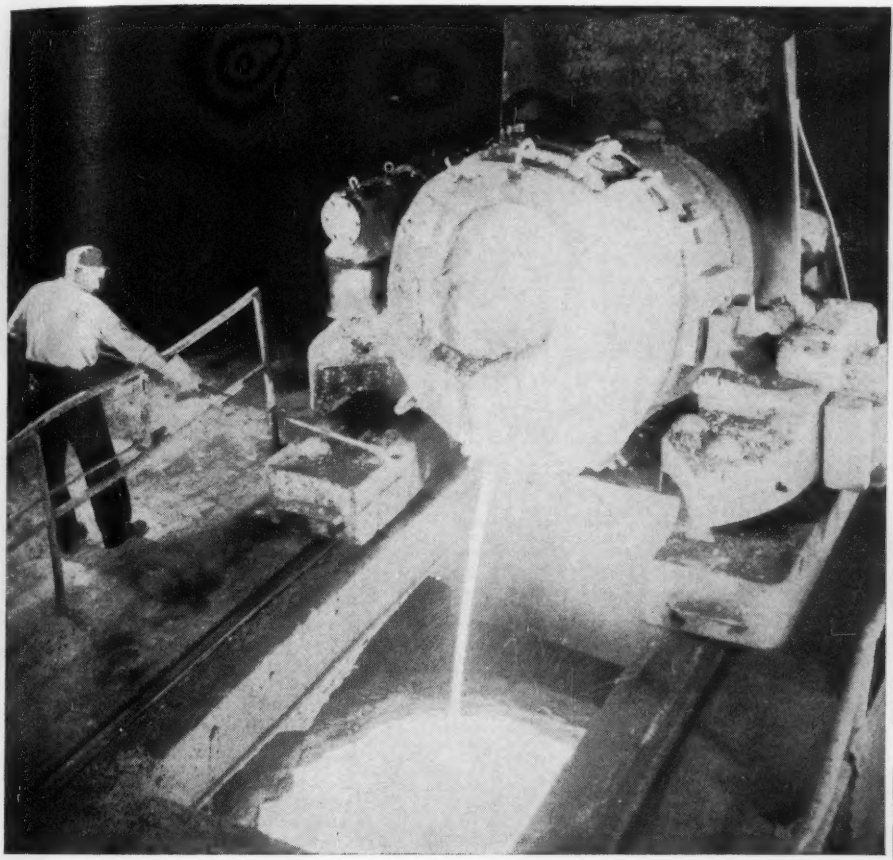

Melting pig iron in the cupolas

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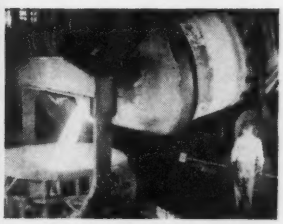

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Laboratory, Practical Inhibitor Papers Planned

Electrical Check on Corrosion; Brine Exposure Are Covered

An unusual method of measuring corrosion, practical in some cases in indicating a rate while regular operation of equipment proceeds uninterrupted, is described in one of the three papers to be given during the Chemical Inhibitor Symposium beginning at 10:15 am March 13. The other papers relate to inhibition of metals in brine and evaluation of inhibitors in the laboratory.

The symposium is concurrent with the Corrosion Principles Symposium.

J. L. Wasco, Dow Chemical Co., Midland, Mich. and George E. Best, Mutual Chemical Division, Allied Chemical and Dye Corp., Baltimore are chairmen.

Abstracts follow:

Electrical Resistance Corrosion Measurements Employing Alternating Currents by W. L. Denman, Dearborn Chemical Company.

An electrical resistance method for measuring corrosion with alternating current based on the creation of a stable voltage drop across metal corrosion specimen when a stabilized alternating current flows through it has been developed. Subsequently the small voltage drop is amplified, rectified and measured. The method may be applied to tubular systems without interrupting operations by using a portion of the piping or a pipe nipple in a by-pass as the corroding specimen.

Resistance of the specimen expressed as equivalent potentiometer millivolts drop through it at the start of a corrosion test serves as the base value and any increase of the base represents corrosion. Plotted against time these increases give a corrosion curve. The fraction of the specimen corroded at any time is equal to the increase in potentiometer reading of the exposed length of the specimen divided by the sum of such increase and the initial exposed potentiometer reading.

The corrosion resistance test cell consists of metal specimens such as strips of shim stock or wire imbedded in glass holders by means of room-temperature-setting epoxy resins.

Variables such as temperature, conductance of the solution, stray currents, etc. influence results and must be considered in using this method.

•

Inhibiting Corrosion of Steel, Aluminum and Magnesium Intermittently Exposed to Brines by George E. Best and John W. McGrew, Mutual Chemical Division, Allied Chemical and Dye Corp.

Prevention of corrosion of metals under continuous exposure to sodium or calcium chloride refrigerating brine is one of the earliest commercial applications of a chemical inhibitor, yet comparatively little has been published about the effectiveness of inhibitors under conditions of discontinuous exposure.

Using an experimental technique designed only to provide comparative data and indicate orders of magnitude rather than precisely determined corrosion rates, the present work establishes that chromate effectively minimizes brine corrosion of mild steel and selected aluminum and magnesium alloys intermittently exposed to brines at ordinary temperatures. The importance of ratio between metal surface area and test solution volume is brought out, as is also the effect of pH through comparison of chromate with bichromate. Roughly quantitative indications of inhibitor consumption are reported.

•

Laboratory Method for Corrosion Inhibitor Evaluation by G. A. Marsh and E. Schaschl, The Pure Oil Company, Crystal Lake, Ill.

A screening method has been developed which permits rapid, convenient testing of inhibitors. Unlike weight-loss methods, this new method is well adapted to follow non-linear corrosion-time curves, such as those commonly found when adsorption-type inhibitors are used. The method makes use of quart bottles containing the corrosive agents; the bottles are rotated end over end at about three RPM. This rotation brings about alternate immersion of test probes where the corrosive system consists of two or more phases. The test probes, built into rubber stoppers, are inserted into the bottles. These probes are used to follow the course of corrosion without re-

(Continued on Page 90)

Best

Denman

Marsh

Schaschl

ABOUT the AUTHORS

WAYNE L. DENMAN—Directing Chemist, Dearborn Chemical Company. He has a BS from Oregon State College (1925), in chemical engineering and a PhD in chemistry from State University of Iowa (1929). He was research chemist, Dearborn Chemical Company 1929-41; chief chemist, Dearborn Chemical Company 1941 and was with U. S. Chemical Warfare Service 1941-1945. He was chief chemist with Dearborn Chemical Company (1945-50). He is a registered professional engineer in Illinois and a member of ACS, ASME, ASTM.

GEORGE E. BEST—Since 1948 he has been occupied with technical service and development work for Mutual Chemical Division, Allied Chemical and Dye Corp. After graduating from MIT in electrochemical engineering, he spent 10 years in process metallurgical research with New Jersey Zinc Co. at Palmerton, Pa. and three years with Pennsylvania Salt Manufacturing Co. at Wyandotte, Mich. as production supervisor. He has been active in NACE affairs. As a section and region official and as a member of the NACE board of directors. He has authored and published several papers dealing with inhibition by chromates.

GLENN A. MARSH received a BS in chemistry from Illinois Institute of Technology in 1945 and a MS in chemistry from Northwestern University in 1946. He began his employment with Pure Oil Co. in 1948. He is enagged in corrosion research.

EDWARD SCHASCHL received a BS in chemical engineering from Illinois Institute of Technology in 1945 and joined Pure Oil Company in 1948 as a process engineer. He is presently doing research in metallurgy and corrosion.

CHEMICAL INHIBTORS

Electrical Resistance Corrosion Measurements Employing Alternating Currents by W. L. Denman, Dearborn Chemical Co., Chicago, Ill.

Inhibiting Corrosion of Steel, Aluminum and Magnesium Intermittently Exposed to Brines by G. E. Best and John W. McGrew, Mutual Chemical Division, Allied Chemical and Dye Corporation, Baltimore, Maryland.

Laboratory Evaluation of Corrosion Inhibitors by G. A. Marsh and Edward Schaschl, Pure Oil Company Research Laboratories, Crystal Lake, Ill.

Technical material published in Corrosion is abstracted in the biennial Bibliographic Surveys of Corrosion published by NACE.

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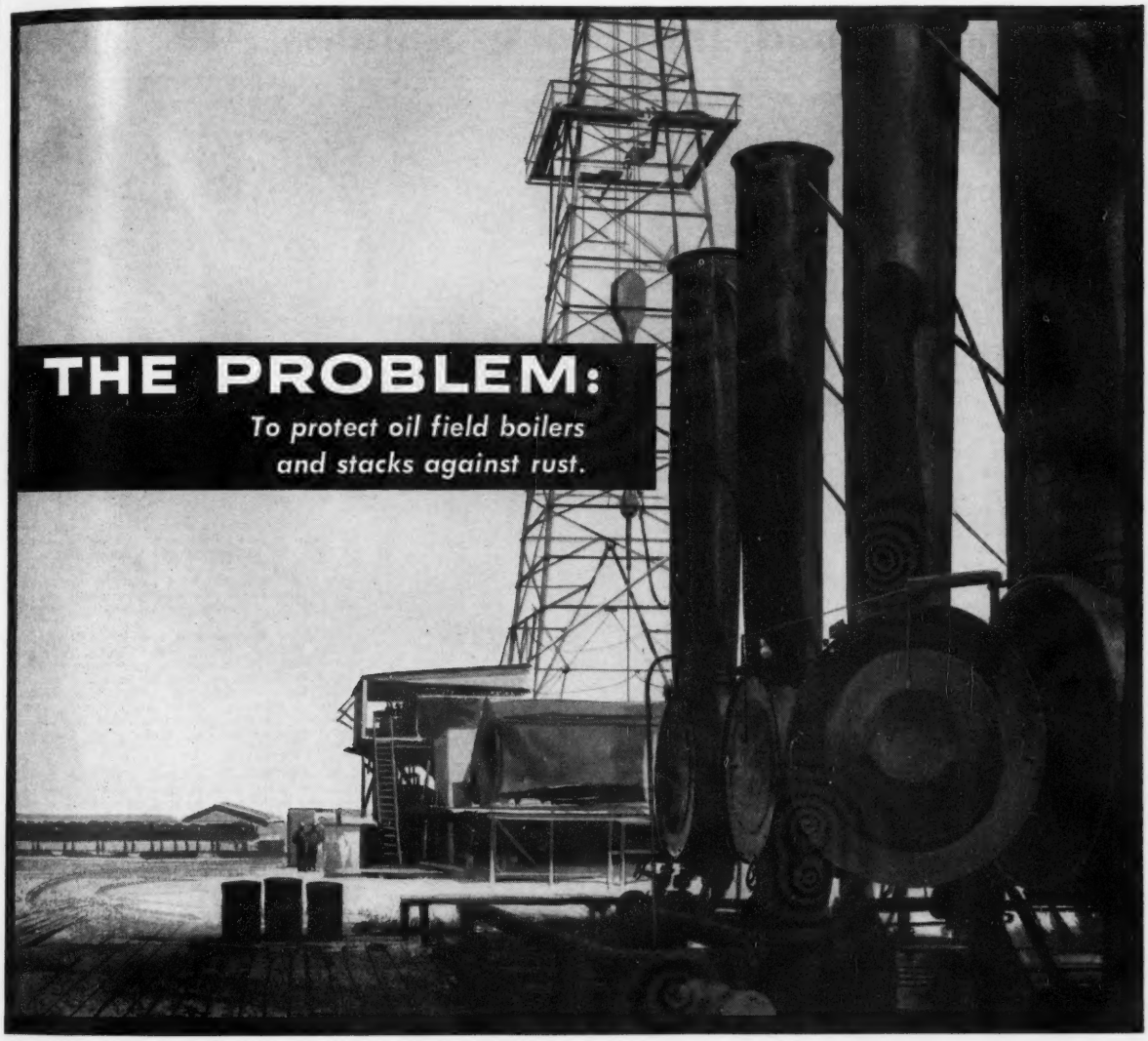

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Naphthenic Acid, Inhibitors, Sulfides Are Topics

Refinery Corrosion Problems Scanned In Six Papers

Unusually wide scope of information is included in the six papers scheduled for the two-part Refinery Industry Symposium to be held beginning at 2 pm Tuesday March 13 and at 2 pm Wednesday March 14. Data on correlation of high temperature sulfide corrosion information, hydrogen blistering in a cracking unit and a refinery paint program, among others, will be given.

R. J. Hafsten, Standard Oil Co. (Indiana), Whiting and J. F. Mason, Jr., International Nickel Co., Inc., New York are chairmen.

The symposium is concurrent: Part 1 with the High Purity Water and Oil and Gas Production Symposia; Part 2 with Power and Communications and Pipe Line Group Discussions.

Available abstracts of papers follow:

Naphthenic Acid Corrosion—An Old Enemy of the Petroleum Industry by W. A. Derungs, N. V. de Bataafsche Petroleum Maatsschappij, The Hague, Netherlands.

Naphthenic Acids is a collective name for organic acids present in various crudes. The constitution of the naphthenic acids is discussed.

Naphthenic acid corrosion of mild steel becomes apparent at operating temperatures upwards 220 C with a maximum at around 280 C. After surpassing a temperature of say 320 C, the corrosion rate decreases gradually. Fluid velocity is of preponderant influence on the rate of naphthenic acid corrosion.

Unfortunately, the critical velocity values below which the corrosion rates become negligible are not yet known.

Methods to counteract naphthenic acid corrosion are discussed.

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Electrical Resistivity Technique for Evaluation of Corrosion Inhibitors by W. L. Terrell and W. L. Lewis, Esso Standard Oil Company, Baton Rouge.

The electrical resistance technique described in this paper has been developed for determining the relative corrosive properties of various hydrocarbon streams. It has also been used very successfully for the screening and evaluation of corrosion inhibitors in these same streams.

This technique is a combination and modification of two known methods of corrosion testing. First, the method of measurement is a modification of the method described by Andrew Dravnieks and Horace A. Cataldi, **Corrosion,** Vol. 10, No. 7, p. 224 (1954). Second, the test solution, temperature, and agitation is an altered method of ASTM D-665-46T "Method of Test for Rust-Preventing Characteristics of Steam-Turbine Oil in the Presence of Water." The amount of corrosion is evaluated by measuring the change in electrical resistance of a carbon steel specimen (.001-inch shim stock) during exposure to the corrosive medium. Corrosion losses can be detected to a fraction of a microinch at any time during a test using the apparatus described here without interrupting the test or use of any special measuring devices or technique. Measurable and reproducible corrosion losses are obtained in a test of six hours' duration. A correlation of the data obtained with the resistivity test with those obtained from retractable coupons and measured metal losses will be presented.

•

A Refinery Paint Program to Cut Maintenance Costs by R. J. Hafsten, H. A. Homan and K. R. Walston, Standard Oil Co. (Indiana) Whiting, Ind.

This paper illustrates the result of an organized effort in a major refinery to reduce maintenance painting costs. Surface preparation is emphasized and the importance of adequate mil thickness is illustrated. Paint quality is assured by means of test panels and field tests in the refinery and test panels exposed in the high ultraviolet sunlight at Coral Gables, Florida. Control is exercised

(Continued on Page 106)

Backensto

Drew

Hafsten

Neumaier

Schillmoller

ABOUT the AUTHORS

BERNARD E. NEUMAIER—He is chief process engineer of Richfield Oil Corp. His responsibilities in the process engineering department include directing and supervising engineers working on general petroleum processing problems and equipment design. He holds a BS in chemical engineering from Pennsylvania State University (1929). He joined Sinclair Refining Company's research and development department in East Chicago in 1929, obtaining a thorough background in thermal and catalytic cracking processes. In 1935 he was promoted assistant division head of the cracking division. He joined Richfield in June 1945 at its Wilmington, Cal. refinery. He is a member of AIChE and of the California Natural Gasoline Association.

CHARLES M. SCHILLMOLLER—He is corrosion engineer of Richfield Oil Corp. He joined the company in August, 1952 as a process engineer in the Wilmington, Cal., refinery and has specialized in corrosion control for the past two years. His early education was in Holland and the Netherland East Indies and he graduated in 1952 from University of Sydney, Australia with a BE in chemical engineering. He was a pilot in the Netherlands Air Force from 1941 to 1947. He is a member of API and NACE.

RAYMOND J. HAFSTEN—Presently Assistant Chief Engineer in the Whiting Refinery Engineering Division, Standard Oil Company (Indiana).

E. B. BACKENSTO—He is senior engineer with Socony Mobil Oil Company in its Paulsboro, N. J. Research and Development Laboratories. He joined Socony after receiving a BS in chemical engineering from Lehigh University in 1943. He had diversified experience in petroleum research before his current assignment in corrosion. He is a member of AIChE, ACS and NACE.

R. D. DREW—Research associate with Socony Mobil Oil Company, in its Paulsboro, N. J. laboratories, he has been with the company since his graduation from Yale University in 1939 with a BS in chemical engineering. His work has been mainly in the development of continuous catalytic cracking and reforming processes. He is a member of AIChE, ACS, Sigma Xi.

R. W. MANUEL—Corrosion engineer, Refinery Engineering Division, Socony Mobil Oil Co., New York, he received a BS in chemical engineering from University of Kansas in 1936. He formerly was with Crane Company Research Laboratories, Chicago; Goodyear Research Laboratories, Akron; Phillips Petroleum Company, Bartlesville, Okla. and Lago Oil and Transportation Co., Aruba, Netherland West Indies.

J. W. SJOBERG—He received a BS from Missouri School of Mines and Metallurgy in 1944, and after two years in the Navy, he received an MS in chemical engineering from the same school. He started with Socony Mobil at its Augusta, Kansas refinery, transferred to the laboratories in 1954 and is now chemical engineer in corrosion research at Socony Mobil Oil Company's Paulsboro, N. J. research and development laboratories. He is a member of ACS and Sigma Xi.

REFINERY INDUSTRY

Part 1

Naphthenic Acid Corrosion — An Old Enemy of the Petroleum Industry by Wm. A. Derungs, N. V. de Bataafsche Petroleum Maatschappij, The Hague, Netherlands.

Electrical Resistivity Technique for Evaluation of Corrosion Inhibitors by W. L. Terrell and W. L. Lewis, Esso Standard Oil Co., Baton Rouge, La.

A Refinery Paint Program to Cut Maintenance Costs by R. J. Hafsten, H. A. Homan and K. R. Walston, Standard Oil Co. (Indiana), Whiting, Ind.

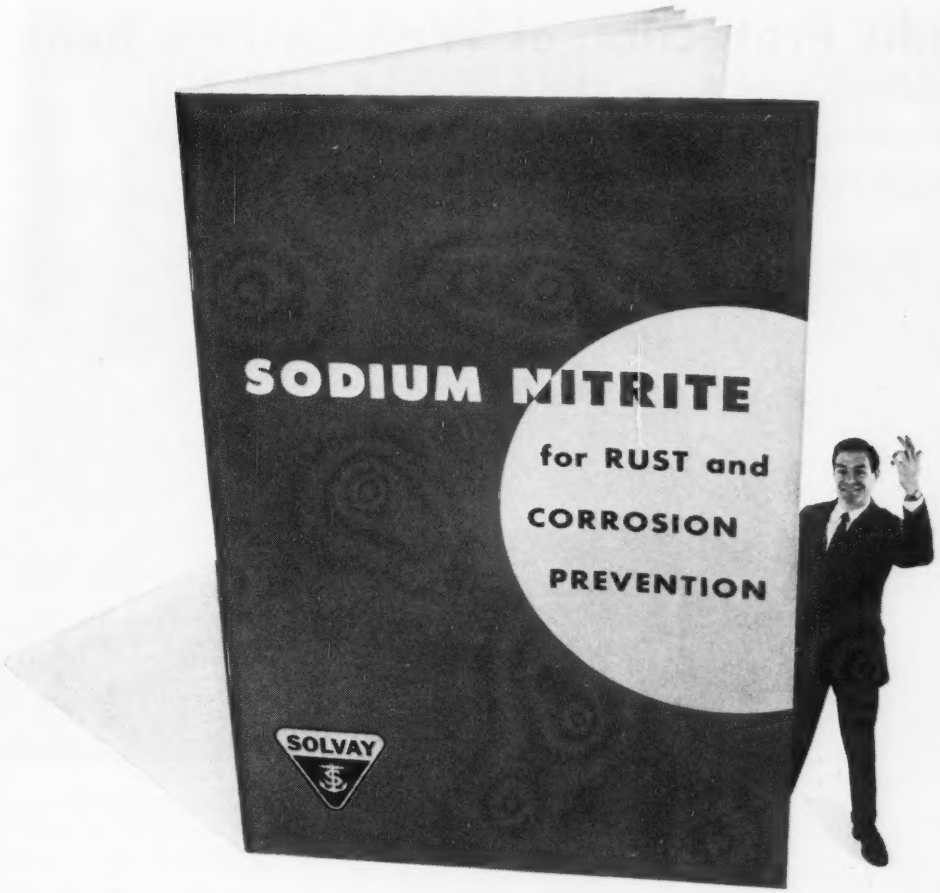
Part 2

How Richfield Tackled Hydrogen Blistering in Its New Fluid Catalytic Cracking Unit by B. W. Neumaier and C. M. Schillmoller, Richfield Oil Corp., Wilmington, California.

High Temperature Hydrogen Sulfied Corrosion in Thermofor Catalytic Reformers by E. B. Backensto, R. D. Drew and J. W. Sjoberg, Socony-Mobil Laboratories, Paulsboro, N. J. and R. W. Manuel, Socony Mobil Oil Co., Inc., New York, N. Y.

Collection and Correlation of High Temperature Sulfide Corrosion Data by G. Sorrell and W. B. Hoyt, M. W. Kellogg Company, New York, N. Y.

High Temperature Hydrogen Sulfide Corrosion in the Presence of Hydrogen by C. H. Samans, Standard Oil Co. (Indiana), Whiting, Ind.



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Cathodic Protection of Well Casings Beneficial

Offshore Platforms Also Scheduled As Topic of Paper

The four papers in the Oil and Gas Production Symposium to be given beginning at 2 pm March 13 cover cathodic protection and other means of protecting oil well casings, protection of offshore drilling platforms and a method of coating crude oil tank bottoms.

W. F. Oxford, Jr., Sun Oil Co., Beaumont and J. L. Battle, Humble Oil and Ref. Co., Houston are chairmen.

The symposium is concurrent with the High Purity Water and Refinery Industry symposia.

Available abstracts follow:

Casing Corrosion—Hugoton Gas Field by W. C. Koger, Cities Service Oil Co., Bartlesville, Okla.

A casing leak survey in the Hugoton gas field was made by the local chapter of the AIME to obtain information with which the casing corrosion problem could be evaluated and the most severely affected areas located. It was determined that leak frequency was relatively low but that leaks usually resulted in decreased deliverability or loss of the well. Because the pool is expected to be productive for another 30 years, the seriousness of the problem was not reflected entirely by current leak frequency.

Work to date indicates current application based on indications derived from surface potential measurements is sufficient to protect the wells and that the required current is obtainable from galvanic anodes. This latter fact is important because each well is located in the center of a section.

Interference from rectifier installations has been found in the field, presenting a new problem in efforts to protect casing cathodically from corrosion.

Ballou

Doremus

Koger

Schremp

Cathodic Protection of Oil Well Casings at Kettleman Hills, California by J. K. Ballou, Standard Oil Co. of California, San Francisco and F. W. Schremp, California Research Corp.

This paper presents information obtained from cathodic protection tests made on three oil well casings of the Kettleman North Dome Unit at Kettleman Hills, California, during the period February 28 through September 1, 1955. The tests showed that cathodic protection is a practical method of controlling external casing corrosion at least to depths of 8000 feet provided sufficient current is used. Current densities on the order of 1.0 to 1.5 ma per sq ft are believed necessary to provide essentially complete protection to wells in the area. Both surface potential and casing potential profile measurements were made during the tests. Inexpensive surface measurements of casing potentials referred to a remote reference electrode can be used to indicate with reasonable accuracy the degree of protection obtained with cathodic protection. Casing potential profile measurements failed to indicate either the degree of protection or when complete protection was achieved.

OIL, GAS PRODUCTION

Casing Corrosion—Hugoton Gas Field by W. C. Koger, Cities Service Oil Co., Bartlesville, Oklahoma.

Cathodic Protection of Mobile Off Shore Drilling Platforms by E. P. Doremus, Cathodic Protection Service, Houston, Texas.

Cathodic Protection Tests Made on Oil Well Casings at Kettleman Hills, California by J. K. Ballou, Standard Oil Co. of California, San Francisco, California and F. W. Schremp, California Research Corp., La Habra, Cal.

Coatings for Crude Oil Tank Bottoms by R. M. Carter, Service Pipe Line Co., Tulsa, Okla.

ABOUT the AUTHORS

JAMES K. BALLOU—Corrosion Engineer with Engineering Department, Standard Oil Company of California, San Francisco, California. He received a BS in electrical engineering from the University of California in 1948, after which he joined Standard Oil of California. He has been active in design and testing of cathodic protection systems for pipelines and other structures since 1950.

W. C. KOGER—He is co-chairman of NACE T-1H on Oil String Casing Corrosion and T-1D on Sour Oil Well Corrosion. A 1944 graduate of University of Arkansas with a BS in chemical engineering, he joined Cities Service Oil Company on graduation and was assigned to refinery research. In 1946 he was transferred to the company's oil production division as corrosion engineer in the West Kansas Division. He currently is head of the Corrosion and Oil Treating Section, Oil Production Division, Bartlesville, Okla.

FRED W. SCHREMP—Group Leader, Oil Field Corrosion Research, California Research Corporation, La Habra, California. He received his PhD in chemistry from the University of Wisconsin in 1950. Prior to joining the California Research Corporation in 1950, he worked for the American Steel and Wire Company and the Manhattan Project. His interests include metallurgical and electrochemical corrosion problems. He is Chairman (1955) of NACE Unit Committee T-1A on Corrosion of Oil and Gas Equipment, Los Angeles Area.

•

NACE Has No Copies Of Conference Papers

No copies of papers presented at the 12th Annual Conference are available from NACE. Authors of papers sometimes prepare preprint versions of their papers in which cases copies may be secured from them. Persons interested in technical material presented are urged to consult CORROSION in which all papers approved by the NACE Editorial Review Subcommittee and the editor of CORROSION are published as they are approved. Non-members of NACE may subscribe to CORROSION at rates indicated on the Contents Page of this issue.

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Five Papers Listed on High Purity Water Agenda

Effects on Ferrous, Non-Ferrous Metals Will Be Outlined

A wide variety of information on complex new problems encountered in handling high purity water, especially at elevated temperatures will be presented during the High Purity Water Symposium beginning at 1:45 pm Tuesday March 13. This symposium will include five papers covering iron corrosion, stainless steels, and aluminum alloys, among other things.

A. H. Roebuck, Continental Oil Co., Ponca City, Okla. and R. U. Blaser, The Babcock and Wilcox Company, Alliance, Ohio are chairmen.

The symposium is concurrent with the Refinery Industry and Oil and Gas Production symposia, both of which begin at 2 pm.

Papers to be given are:

Corrosion Studies in High Temperature Water by a Hydrogen Effusion Method by M. C. Bloom, M. Krulfeld, W. A. Fraser and P. N. Vlannes, Naval Research Laboratory.

Corrosion rate data for low carbon and stainless steel in high temperature water will be presented showing the effects of various pretreatments of the metal and various additions to the water.

•

Corrosion of Iron in High Temperature Water by David L. Douglas, F. J. Shipko and F. C. Zyzes, Knolls Atomic Power Laboratory, Schenectady, New York.

In order to better understand the corrosion of ferrous alloy systems, a study of the kinetics and mechanism of the reaction of pure iron with high temperature water has been undertaken in this laboratory. A method has been developed for measuring the amount of hydrogen evolved when iron coupons are exposed to high temperature water in auto-claves. Using this, some basic corrosion rate data have been accumulated.

Kirkendall-type experiments, using $Ni^{63}O$ as a boundary marker, have established that, in the temperature range 240 - 360 C, the reaction proceeds by diffusion of iron ions through the magnetite film.

In addition, an investigation of Schikorr's reaction,

$$3\,Fe(OH)_2 \rightarrow Fe_3O_4 + H_2 + 2H_2O,$$

has been carried out. The results indicate that this may be rate controlling at sufficiently low temperatures, i.e., corrosion will not take place at temperatures below that above which this reaction proceeds at a noticeable rate.

•

Corrosion of Stainless Steels in Supercritical Water by H. A. Pray and W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio.

The corrosion behavior of ten stainless steels (representing hardenable and nonhardenable grades) has been determined by static tests in degassed supercritical water at 800, 1000 and 1350 F at a pressure of 5000 psi. The materials were evaluated on the basis of weight gain and metallographic examination of samples after exposure to the selected test conditions.

Binger

Douglas

Draley

ABOUT the AUTHORS

DAVID L. DOUGLAS—Currently working on electrochemistry since his 1955 transfer to General Electric's research laboratory, he formerly was on the staff of Knolls Atomic Power Laboratory, operated for AEC by General Electric. He received a PhD in chemistry from California Institute of Technology in 1950 and spent a year in postdoctorial work in radiocarbon dating at California Institute of Technology. He is now research associate, Physical Chemistry Section at the General Electric Schenectady, N. Y. research laboratory.

JOSEPH E. DRALEY—Active in corrosion research since 1942, when he joined the Metallurgical Laboratory, University of Chicago, he has been in the atomic energy field almost continuously since with Kellex Corp., Oak Ridge National Laboratory and Argonne National Laboratory. His work has been largely with corrosion mechanisms of aluminum, uranium and zirconium and their alloys in pure water and dilute solutions. He has written numerous "projects" publications and has been an active speaker on corrosion subjects for NACE, The Electrochemical Society and others. He currently is vice-chairman of the Electrochemical Society's Corrosion Division.

W. W. BINGER—Assistant Chief of the Chemical Metallurgy Division, Aluminum Research Laboratories, Aluminum Company of America, he joined Alcoa in 1943 and took his present position in 1953. He has been concerned chiefly with the development of applications of aluminum alloys in the chemical industry. He has a BS in chemical engineering, University of Wisconsin (1943). He has published many papers dealing with the corrosion of aluminum.

HIGH PURITY WATER

Corrosion Studies in High Temperature Water by a Hydrogen Effusion Method by M. C. Bloom, M. Krulfeld, W. A. Fraser and P. N. Vlannes, Naval Research Laboratory, Washington, D. C.

The Corrosion of Iron in High Temperature Water by D. L. Douglas, General Electric Research Laboratory, Schenectady, N. Y. and F. C. Zyzes, Knolls Atomic Power Laboratory, Schenectady, N. Y.

Corrosion of Stainless Steels in Supercritical Water by H. A. Pray and W. K. Boyd, Battelle Memorial Institute, Columbus, Ohio.

Corrosion Resistant Aluminum Alloys for Use in Water at Elevated Temperatures by J. E. Draley and W. E. Ruther, Argonne National Laboratory, Lemont, Illinois.

Aluminum Alloys for Handling High Purity Water by W. W. Binger and C. M. Marstiller, Aluminum Company of America, New Kensington, Pennsylvania.

The Armco 17-4PH, Armco 17-7PH and Hastelloy F alloys were the most resistant materials at both 1350 F and 1000 F. Inconel X, Type 302 stainless and Allegheny A-286 were severely attacked at both 1350 F and 1000 F, whereas the Hastelloy X and Type 410 stainless show heavy attack at 1350 F only. Type 347 stainless steel, although exhibiting only moderate weight gains, was severely pitted after exposure at 1350 F. Some pitting was also observed on the sample of Type 309 stainless.

In supercritical water plus hydrogen at 1000 F, the Allegheny A-286 alloy was the only material showing a significant reduction in corrosion resulting from the presence of hydrogen. The reason for this is not known.

All alloys tested had excellent resistance to 800 F degassed supercritical water after an 84-day exposure.

In general, the corrosion in degassed supercritical water at 1350 F was intergranular in nature, whereas, at 1000 F, only the Inconel X material was selectively penetrated along grain boundaries. All alloys suffered some decarburization and carbide precipitation after exposure at 1350 F. No decarburization or significant phase changes were observed for samples exposed at 1000 F.

•

Corrosion Resistant Aluminum Alloys for Use in Water at Elevated Temperatures by J. E. Draley and W. E. Ruther, Argonne National Laboratory, Lemont, Ill.

Commercial aluminum alloys suffer rapid disintegration in water at temperatures significantly above 200 C. The phenomenon can be prevented by anodic protection. One practical method of achieving this is by alloying the aluminum with nickel. Such alloys suffer only "normal" attack, showing only moderate corrosion rates. Corrosion properties and rates are given for these alloys and the effects of other alloying constituents are described.

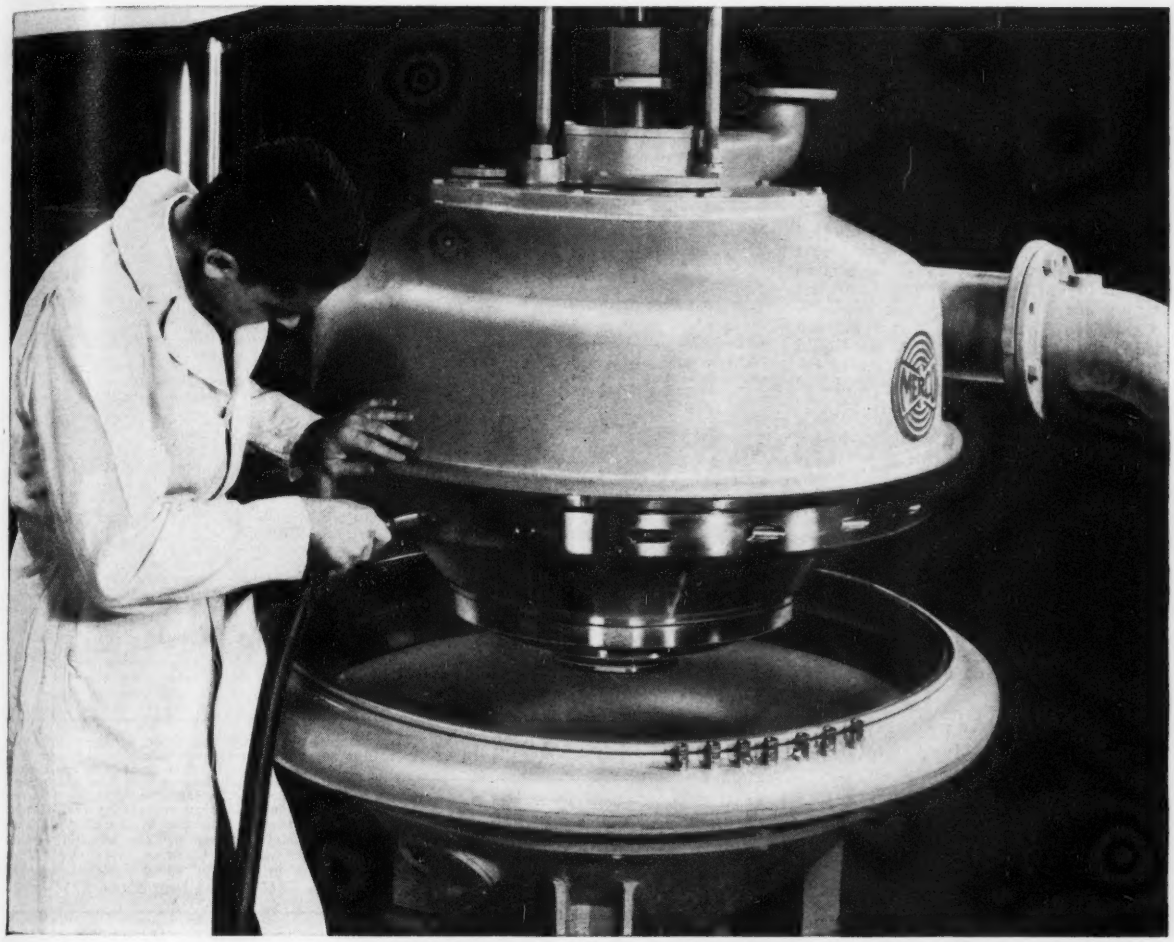
•

Aluminum Alloys for Handling High Purity Water by W. W. Binger and C. M. Marstiller, Aluminum Research Laboratories, New Kensington, Pa.

Aluminum alloys have been used for storage and distribution systems handling distilled water for over twenty years. Recently, it became possible to investigate experience with some 30 distilled water systems which had been in use for various periods of time up to 24 years. Many of these systems had been made entirely of aluminum, several were entirely of tinned copper or brass and others were a combination of materials including aluminum.

Results indicate that aluminum alloy storage tanks, tubing, fittings and valves are highly satisfactory for handling dis-

(Continued on Page 90)



The separating force produced by this Merco centrifuge is made practical by the strength of its high speed rotor bowl, machined from cast stainless steel with a high nickel content, produced by Electric Steel Foundry Company, Portland, Oregon. Weight of the all-stainless steel rotor assembly on the unit shown above totals 1600 lbs. This centrifuge has a large continuous through-put capacity. In many plants, Merco units run continuously for 24 hours, virtually unattended. Manufactured by Merco Centrifugal Company, San Francisco, California.

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Statistical Methods for Chemical Industry Scanned

Three Papers for Chemical Industry Involve Calculations

Three of the eight papers scheduled for presentation during the two-part Chemical Industry Symposium pertain to statistical methods. Part 1 of the symposium will begin at 9 am Wednesday, March 14 and Part 2 at 2 pm the same day. Other topics include liquid fertilizer corrosion, effects of metal cations, stress corrosion cracking of Monel and a study of heat flux effect.

J. J. Heger, United States Steel Corp., Pittsburgh and B. J. Philibert, Olin-Mathieson Chemical Corp., Baltimore are chairmen.

The symposium is concurrent with: Part 1, Steel Metallurgy and General Pipe Line; Part 2, Power and Communications and Pipe Line Group Discussions.

Available abstracts follow:

Effects of Metal Cations on the Corrosion of Iron in Acids by Harry C. Gatos, Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass.

The corrosion of iron was studied in 1N H_2SO_4, 1N HCl, and 1N HOAc containing oxidizing, reducing, or stable metal cations. Oxidizing cations (Fe^{+++}, Ce^{++++}, Cu^{++} and $Cr_2O_7^{--}$) increased the corrosion rate of iron in these acids. The increased rate was found to be a linear function of the cation concentration for the concentration range studied (up to 0.1 g. ions/l). For the same oxidation-equivalent concentration the corrosion rate was proportional to the valence change which the metal cations underwent during the corrosion process. Reducing cations (As^{+++} and Sn^{++}) decreased considerably the corrosion of

(Continued on Page 87)

Allen

Aziz

Cogshall

Fisher

Gatos

Shockley

Whitney

Williams

ABOUT the AUTHORS

HARRY C. GATOS—Until recently with the Engineering Research Laboratory, Engineering Department, E. I. du Pont de Nemours and Co., Inc., he is now with the Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Mass. After doing his undergraduate work in chemistry at the University of Athens, Greece, he received an MA in chemistry from Indiana University and a PhD in inorganic chemistry from MIT. Prior to joining du Pont, Dr. Gatos served for a year as research associate in the department of metallurgy at MIT. His main research interests are in the fields of electrochemistry, metallic corrosion and chemistry of metal surfaces.

H. W. SHOCKLEY—Currently chairman of the Subcommittee on Surface Preparation and Paint Application of the E. I. du Pont de Nemours & Co., Inc. Protective Coatings Committee, for the past 20 years he has been maintenance consulting engineer to all duPont plants. In this latter capacity he assists plants in establishing maintenance programs and in measuring performance. A graduate of Lehigh University with a BS in mechanical engineering (1918) he has been mechanical supervisor in the shipbuilding industry, plant engineer for the Virginia Albarene Corp. and has held numerous supervisory positions at duPont in the maintenance field.

(Continued on Page 87)

CHEMICAL INDUSTRY

Part 1

Corrosion of Metals by Liquid Fertilizer Solutions by D. C. Vreeland and S. H. Kalin, Applied Research Laboratory, United States Steel Corp., Monroeville, Pennsylvania.

Effects of Metal Cations on the Corrosion of Iron in Acids by H. C. Gatos, Massachusetts Institute of Technology, Lexington, Mass.

Stress Corrosion Cracking of Monel in Hydrofluoric Acid by H. R. Copson and C. F. Cheng, International Nickel Co., Inc., Bayonne, N. J.

Studies on Effect of Heat Flux on Corrosion by F. L. Whitney, Jr. and A. O. Fisher, Monanto Chemical Company, St. Louis, Mo.

Part 2

Reducing Maintenance Painting Costs in the Chemical Industry by M. L. Monack, H. W. Shockley and J. R. Allen, E. I. DuPont de Nemours and Co., Inc., Wilmington, Del.

Estimating for Maintenance Painting by R. F. Williams and J. H. Cogshall, Pennsylvania Salt Mfg. Company, Philadelphia, Pennsylvania.

Comparison of Alternatives by Captialized Cost by F. C. Jelen, Solvay Process Div., Allied Chemical and Dye Corp., Syracuse, N. Y.

Application of Statistical Theory of Extreme Values to the Analysis of Corrosion Pit Depth Data by P. M. Aziz, Aluminium Laboratories, Ltd., Kingston, Ont.

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ABOUT the AUTHORS

(Continued From Page 86)

J. R. ALLEN—As a member of the staff at the Engineering Research Laboratory, E. I. duPont de Nemours & Co., Inc., he has been occupied in research and development of non-metallic materials of construction for chemical plants and equipment. A graduate of Georgia Institute of Technology in 1943 with a BS in ceramic engineering, he served three years in the army before joining duPont.

F. L. WHITNEY, JR.—Mr. Whitney, 1955-56 president of NACE, has been active in sectional, regional and national affairs of the association for many years. He is corrosion consultant for the Engineering Department, Research and Engineering Division, Monsanto Chemical Co., St. Louis. His activities include not only corrosion engineering but he has been active in developing and participating in corrosion education activities. He obtained a BS in chemistry from Norwich University in 1930. Prior to his employment with Monsanto he was with E. I. duPont de Nemours & Co., Inc. in various capacities.

A. ORMAN FISHER—Corrosion engineer for the Merrimac Division, Monsanto Chemical Co., since April 1954 he has been occupied with company-wide corrosion problems in Monsanto's St. Louis office. He holds a BS in chemical engineering from Northeastern University, Boston, Mass. and is active in NACE affairs.

P. M. AZIZ—He is concerned principally with basic research on the corrosion mechanisms of aluminum on which he has published six papers. He holds a BASc in chemical engineering and MA and PhD degrees in physical chemistry from the University of Toronto where he studied surface tension in aqueous sulfuric acid solutions and transference phenomena in molten salts. He has been on the staff of Aluminium Laboratories, Ltd., Kingston, Ont. since 1949. He spent a year at University of Chicago developing a radiotracer technique for identifying cathodic sites on aluminum surfaces. He was the recipient of the 1945 NACE Junior Award for the best corrosion paper published in CORROSION by an author under 35 years of age.

Statistical Methods–

(Continued From Page 86)

iron in acids, whereas stable cations (Fe^{++}, Mn^{++}, Cr^{+++}, and Ni^{++}) showed no effect.

The action of the various cations at the local cells was explained on the basis of corrosion data and electrode potential measurements.

•

Stress Corrosion Cracking of Monel in Hydrofluoric Acid by H. R. Copson and C. F. Cheng, International Nickel Co., Bayonne, N. J.

It has been known for some time that Monel is susceptible to intergranular stress corrosion cracking in fluosilicic acid. It was surprising, however, to find "K" Monel bolts breaking in transgranular fashion in hydrofluoric acid vapor. The diagnosis that these failures were stress corrosion cracking was confirmed by reproduction of the cracking in the laboratory. Several similar case histories are reviewed and a number of qualitative laboratory experiments on the stress corrosion cracking of Monel and some other high nickel alloys in hydrofluoric acid environments are described. The number and path of the cracks is influenced by composition, cold work, heat treatment, stress, time and conditions of exposure. Cracking is most prone to occur where corrosion rates are high, such as in moist, aerated vapor. This suggests that hydrogen may play a part in the cracking. Means of avoiding the cracking are discussed.

•

Some Studies on Effect of Heat Flux on Corrosion by F. L. Whitney, Jr. and A. O. Fisher, Monsanto Chemical Co., St. Louis.

Laboratory techniques for testing the effect of heat flux and skin temperatures upon corrosion rates of 316 stainless steel, steel, Nionel and cast iron in various environments are described. Advantages and disadvantages along with supporting evidence are given for three practical approaches to this fundamental study in the laboratory.

Based on the data thus far obtained, skin temperature rather than heat flux has been found to be the controlling factor in the corrosive environments investigated. Heat removed from the corroding surface through agitation and/or other methods appears to be the most practical means of increasing heat flux input without excessively increasing corrosion rate.

Preliminary results indicate the superiority of these techniques over the customary immersion tests for obtaining corrosion data involving heat transfer conditions. Continued research on these methods should lead eventually to development of limiting skin temperatures for various metals in specific environments. Practical application of the data should form a sound basis for predicting plant corrosion rates in heat transfer equipment.

•

Reducing Maintenance Painting Costs in the Chemical Industry by M. L. Monack, H. W. Shockley and J. R. Allen, E. I. du Pont de Nemours & Co., Wilmington, Del.

Maintenance painting costs in the chemical industry can be reduced appreciably by taking measures necessary to increase the life of coatings and by cutting their application cost. Longer life can be obtained by following the three primary

(Continued on Page 106)

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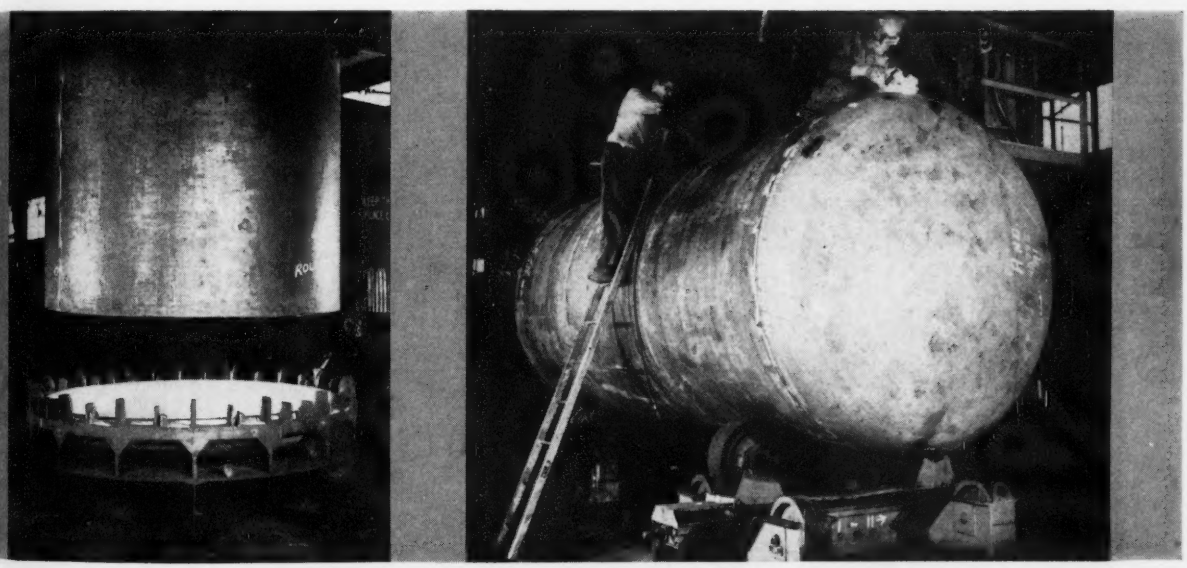

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3798

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Pipe Line Symposium Covers Filtration, Statistics

Cathodic Protection Of Semi-Marine Line Also Detailed

An interesting theory about underground corrosion which will be significant in problems related to economics will be outlined in one of the four papers in the Pipe Line General Symposium. The symposium will begin at 9 am Wednesday, March 14. Other papers cover filtration, performance tests on pipe line coatings and cathodic protection of a semi-marine pipe line.

L. G. Sharpe, Napko Paint and Varnish Co., Houston and R. C. Martin, Plantation Pipe Line Co., Atlanta are chairmen.

The symposium is concurrent with Chemical Industry and Power and Communications symposia.

Available abstracts follow:

Experiments Employing Diatomaceous Earth in Products Pipe Line Filtration by Ivy M. Parker, Plantation Pipe Line Company, Atlanta, Ga.

The fineness and slimness of sediment in a well inhibited products pipe line makes its removal by direct filtration very difficult, because excessive pressure drops are built up by very small quantities of material. A section of four-inch pipeline has been equipped with injection equipment, to add diatomaceous earth to flowing stream, and filter, to receive dirt and injected earth. Experiments to date have employed a diatomaceous earth with high flow characteristics. This material is used both as precoat and as a filter aid. Efficiency of dirt removal is excellent. Continuous injection of filter aid greatly extended filter life when injected at either of two points: 1) Thirty feet from the filter; 2) At up stream station, 37 miles away.

•

An Outline of a Physical Theory on Underground Corrosion by Gordon N. Scott, Los Angeles, Cal.

From a theoretical approach an attempt is made to account for the rate of accumulation of leaks on a pipe line. In addition to the theoretical development the scope of the subject includes a display of evidence in support of the theory and a discussion of consequences of practical importance.

The present paper is limited to an outline of the theory. It begins by accepting the familiar assumption that the corrosion rate decays inversely with its progress. If for extensive structures it is assumed that the effective electrochemical potentials at work are essentially constant, it then follows that the dominant variable is the environmental electrochemical conductivity. Thus is related the total corrosion to time, the electrochemical potentials extant and soil conductivity.

Since at a fixed time the corrosion at each point of attack is associated with a value of conductivity, the distribution of corrosion follows that of the conductivity, the logarithm of which is normally distributed. At this point use is made of modern mathematical statistics to relate maximum corrosion to the area associated therewith. A similar analysis relates the maximum corrosion to pit depth. The introduction of the wall thickness of the pipe into the analysis completes the development whereby the trend of leaks on pipe lines may be traced.

Importance of the effort lies not only in the measure of success attained in the accounting but in the novel and practical conclusions which have resulted. The complete work is regarded as a substantial contribution to the theory of underground corrosion.

Whitley

Parker

ABOUT the AUTHORS

IVY M. PARKER—Technologist for the Plantation Pipe Line Company, Atlanta, since 1945. She received a AB from West Texas State Teachers' College and a AM and PhD from the University of Texas. She was assistant professor of chemistry at Mary Hardin-Baylor College 1934-1935, analytical chemist for the Shell Oil Company 1936-1943 and senior research chemist for the J. S. Abercrombie Company 1943-1945. Dr. Parker's fields of work include development of petroleum solvents, scale and corrosion control in refinery cooling water and internal corrosion of product pipe lines. A member of NACE since 1944 she is presently editor of Corrosion, chairman of Unit Committee T-2E on Internal Corrosion of Product Pipe Lines and Tanks. Dr. Parker also is a member of the American Chemical Society, Institute of Chemists and Georgia Academy of Science.

GORDON N. SCOTT—He is a consulting engineer in Los Angeles. His activity in corrosion matters extends to 1928 when he worked for Mid-Continent Petroleum Corp. at Tulsa. He has made extensive studies of corrosion while at the National Bureau of Standards, is the author of numerous technical papers on various aspects of corrosion control, especially underground, and has been instructor at corrosion control short courses in California. He received the NACE 1955 Speller Award for his work in corrosion engineering.

GENERAL PIPE LINE

Cathodic Protection of Certain Semi-Marine Pipelines by B. J. Whitley, Jr., Tennessee Gas Transmission Co., Houston, Texas.

Experiments Employing Diatomaceous Earth in Products Pipe Line Filtration by Ivy M. Parker, Plantation Pipe Line Co., Atlanta, Ga.

Performance Tests on Pipe Line Coatings by H. W. Walquist, Ebasco Services, Inc., New York, N. Y.

An Outline of a Physical Theory of Underground Corrosion by Gordon N. Scott, Los Angeles, California.

Electrical Check—

(Continued From Page 78)

quiring the bottles to be opened. A probe consists of a corroding specimen (metal ribbon) to which is attached a protected specimen serving as a temperature-compensating element. These specimens form two arms of a resistance-measuring bridge. Electrical leads, brought through the rubber stopper to the outside of the bottle, permit the probe to be connected when desired to a bridge circuit which is used to measure the resistance of the corroding specimen. The bridge circuit internally converts any change in resistance to loss of metal thickness. The corrosion loss in millionths of an inch is read directly from a meter and can be followed conveniently during the course of the test. Several applications of the method are discussed.

Five Papers Listed—

(Continued From Page 84)

tilled water and do not cause significant contamination of the water being handled.

The increased use of the ion exchange method for purifying water has required equipment fabricated from materials in which such a water could be handled with a minimum of pick-up and discoloration. Since many processes require large quantities of a water of very low total solids content, it was natural to consider aluminum alloys for the fabrication of storage tanks and piping for handling demineralized water because of the many successful applications of aluminum alloys handling distilled water.

•

Corrosion is indexed annually by Engineering Index.

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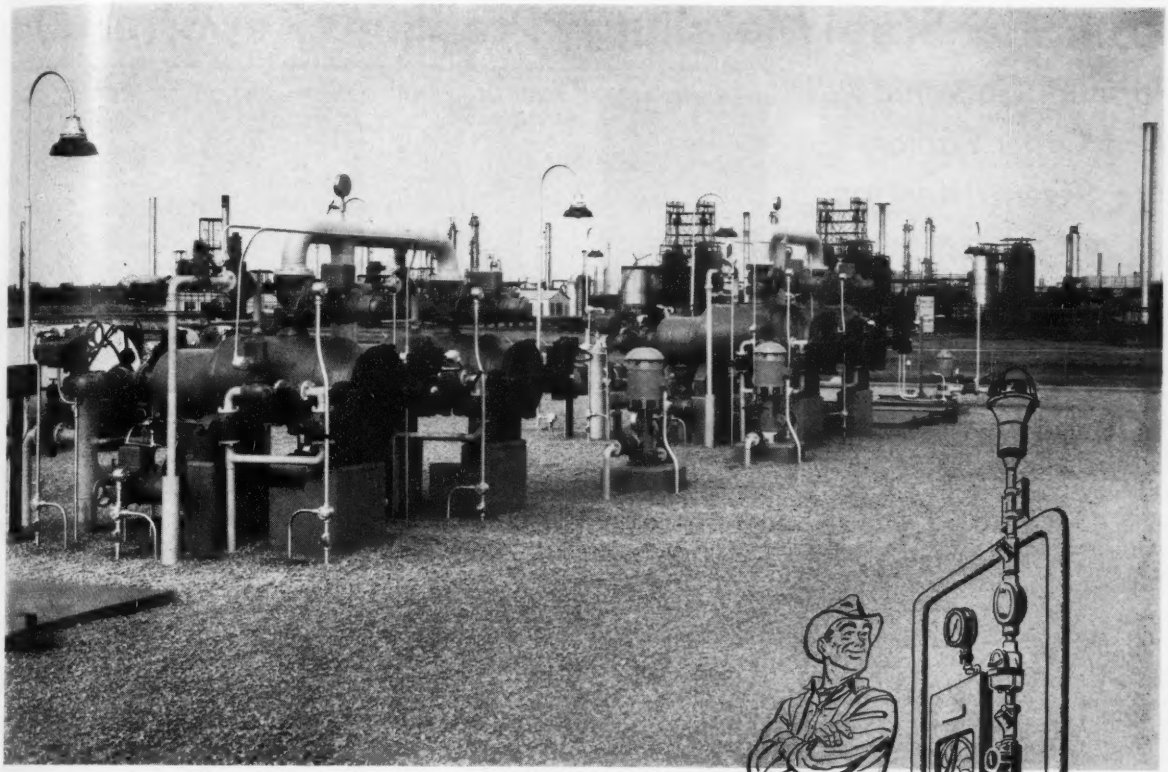

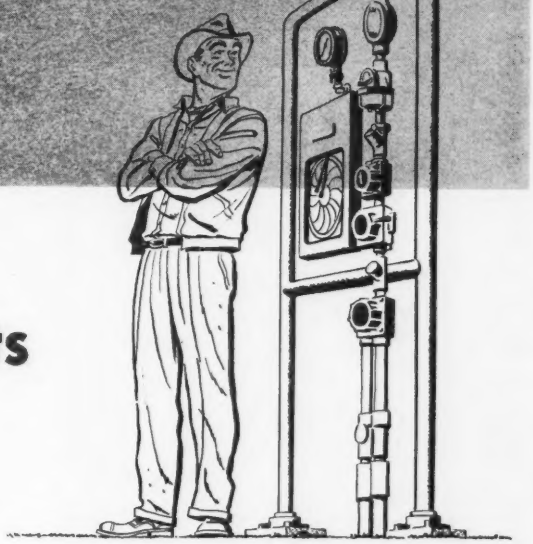

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Complex Steel Metallurgy Problems Reported On

Fatigue, Galvanic And Other Factors Are Given Attention

Golan

Krickl

Radd

Shock

Numerous complex metallurgical problems associated with corrosion are developed in five papers in the Steel Metallurgy and Corrosion Symposium to be held beginning at 8:45 am March 14. Among the topics to be discussed are iron carbides and impurities in low carbon steel, how surface properties affect corrosion of tin plate and a study of galvanic corrosion.

F. J. Radd, Continental Oil Co., Ponca City, Okla. and F. L. Current, Oil Well Supply Co., Oil City, Pa. are chairmen.

The symposium is concurrent with the Chemical Industry and General Pipe Line Symposia.

Abstracts of papers follow:

The Role of Iron Carbides and Impurities in the Corrosion of Plain Carbon Steels by D. A. Shock, F. J. Radd, R. L. McGlasson and L. H. Crowder, Continental Oil Company, Ponca City.

A detailed investigation into the electrochmeical system of the iron—iron carbide cell has been made. Origins and characteristics of this cell and its effect on the corrosion behavior of plain carbon steels are defined. High speed, high sensitivity polarization curves have been obtained which show the corrosion roles of the amount and form of the iron carbide present in a steel. The role of iron carbides in the normal rusting process is shown kinetically.

•

Steel Surface Properties Affect Internal Corrosion Performance of Tin Plate Containers by A. R. Willey, Research Division, American Can Co., Barrington, Ill. and J. L. Krickl, Technical Service Division, American Can Co., Maywood, Ill.

Two easily performed laboratory tests have been developed which give results correlating with internal corrosion performance of paint electrolytic tinplate containers. One, the "rate of pickling" test, measures a permanent surface property of the steel arising in the annealing operation. The other, the "iron solution" test, measures the effect of certain factors governing the nature of the steel surface prior to electrotinning and to some extent the effect of the plating operation itself.

Tin plate manufacturers have used these tests as guides in improving the corrosion resistance of their product. The described tests, however, are not entirely adequate to account for all the existing variations in corrosion performance believed to be related to steel surface characteristics. Additional work is required.

•

Influence of Temperature on Corrosion Fatigue by I. Cornet, and Simcha Golan, University of California, Berkeley.

This investigation deals with the effect of temperature upon corrosion fatigue between 80 and 180 F. All tests were of the single stage type in a 2.5 percent NaCl solution. Apparatus used was a modification of the Kenyon-Rotating-Arc machine. Two types of steel were tested. It was observed that corrosion fatigue properties at 180 F show definite improvement over those at room temperature. This improvement seems to lie in the kind of pits developed and their distribution along the surface.

Apparatus designed and used in this investigation proves to be versatile for corrosion fatigue tests under various conditions. It affords easy control of most variable existing in corrosion fatigue and it is especially suitable for qualitative studies of various kinds.

•

A Statistical Corrosion Fatigue Study of a Plain Carbon Steel by F. J. Radd and R. L. McGlasson, Continental Oil Co., Ponca City, Okla.

Two different steels having the same nominal AISI 1036 analysis but having different microstructures were tested in statistical corrosion fatigue. These steels were different primarily as to their having banded or non-banded microstructures. The microstructural differences are shown to be influential as to the corrosion fatigue life and to the corrosion rate effects in acids. The differences observed are shown to be related to sulfide and other inclusions distributions. The tests show that statistical corrosion fatigue testing affords quite unusual measurements—less data scattering is observed with statistical corrosion fatigue than with statistical air fatigue testing.

•

A Study of Galvanic Corrosion by Dr. James T. Waber, Los Alamos Scientific Laboratory, Los Alamos, N. M.

Distribution of potentials within a corrodent has been analyzed using several geometric arrangements of electrodes which lie in a common surface. Polarization has been assumed to follow Wagner's useful relation as it varies from point to point on the electrode in response to the local corrosion current. The distribution of the corrosion attack over the anode has been studied also.

Two important results are:

1. There is a size effect—the detailed behavior depends to a great extent on whether the electrodes are larger or smaller than Wagner's polarization parameter.

2. Potential of a galvanic couple depends on the relative amounts of the two electrodes, as well as on their open cell potentials.

•

Steel Surface Properties Affect Internal Corrosion Performance of Tin Plate

(Continued on Page 102)

STEEL METALLURGY

The Role of Iron Carbides and Impurities in the Corrosion of Plain Carbon Steels by D. A. Shock, F. J. Radd, R. L. McGlasson and L. H. Crowder, Continental Oil Company, Ponca City, Oklahoma.

Steel Surface Properties Affect Internal Corrosion Performance of Tin Plate Containers by A. H. Willey, American Can Co., Barrington, Ill. and J. L. Krikl, American Can Co., Maywood, Ill.

The Influence of Temperature on Corrosion Fatigue by I. Cornet and Simcha Golan, University of California, Berkeley, California.

A Statistical Corrosion Fatigue Study of a Plain Carbon Steel by F. J. Radd and R. L. McGlasson, Continental Oil Co., Ponca City, Okla.

A Study of Galvanic Corrosion by J. T. Waber, Los Alamos Scientific Laboratory, Los Alamos, New Mexico.

ABOUT the AUTHORS

D. A. SHOCK—Research Group Leader, Research Laboratory Continental Oil Co., Ponca City, Okla., he was in charge of corrosion research problems on the staff of the University of Texas and formerly was employed by International Minerals and Chemical Corp. and Dow Chemical Co., Midland, Mich. He is a member of NACE, ACS and holds an engineering degree from Colorado College, Colorado Springs, Col. and an MS in chemistry, University of Texas. He is active on NACE technical committees and has published many papers on oil well and general petroleum corrosion problems.

A. R. WILLEY—Senior research engineer at American Can Company's Research Center at Barrington, Ill. he has done extensive experimental work on development of special methods to evaluate tin plate performance, especially its corrosion resistance. His recent work includes a study on the corrosivity of foods. He has published a paper on an electrolytic method for determining tin coating weights. He received a PhD in chemistry from University of Wisconsin and has been with Canco since 1937.

J. L. KRICKL—For the past seven years he has worked chiefly on problems of evaluating corrosion resistance of finplate and of transplating improvements in plate quality into practical measures of tin conservation. With the Metallurgy Group of American Can Company's Technical Service Division. He joined the company after receiving a MS from St. Mary's College and an MS in chemistry from University of Illinois.

SIMCHA GOLAN—Presently with Kaiser Engineers, Oakland, Cal. he received a BS in mechanical engineering from the University of California at Berkeley in June 1953 and did graduate work on the same campus receiving an MS in 1955. His master's thesis was titled "The Influence of Temperature on Corrosion Fatigue."

•

Indexes to Corrosion's Technical Section, Technical Committee Activities Section and Corrosion Abstract Section are published annually in the December issue.

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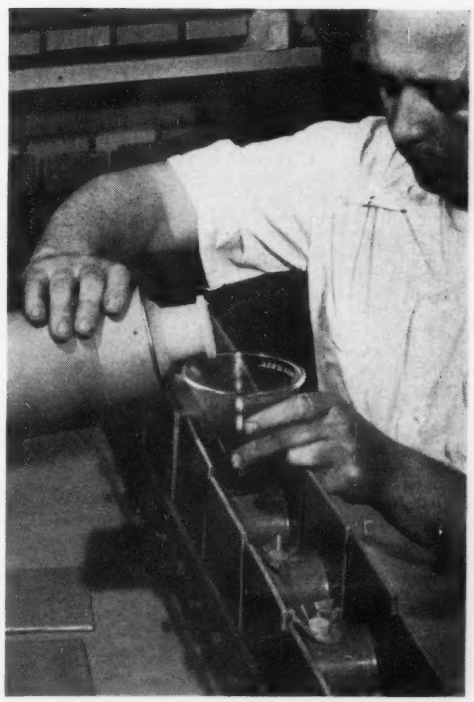

By such simple yet reliable means as test cells, resistance of *various* drum lining formulations to any one specific product is readily determined. Similarly, resistances of one particular lining to a whole range of chemicals is just as easily gauged.

THE AIMS

United Chromium makes such tests by the hundreds of cells. This effort is aimed at improving existing coatings for drum lining service; at sizing up the worth of newly developed coating materials; at helping processors find the one best lining for a particular product to be packaged, shipped or stored in drums.

Coatings meeting chemical resistance requirements are double-checked for impact resistance, adhesion, film continuity and thickness, distensibility, and flexibility.

THE FINDINGS

This work has produced reliable and valuable information. With just four basic coating types, a tremendous variety of products and chemicals can be handled in metal containers. These four include a Unichrome vinyl, phenolic, epoxy and plastisol series of drum linings.

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For important application data and typical usages of these Unichrome Drum Linings, send for Bulletin DL-2.

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Coating 5300 bakes at 350° to 365°F, won't chip, and withstands a wide range of corrosive materials. A number of firms are available that can apply Coating 5300 for any plant without the required baking facilities.

Bulletin VP-1 gives more data on Unichrome Plastisols.

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Cables and Stray Currents Are Scheduled Topics

Testing of Wrappings Also to Be Covered In 4-Paper Session

Lead sheathed cable corrosion problems are considered in three of the four papers in the Power and Communications Symposium. The fourth paper covers testing of wrappings for buried structures. This symposium begins at 2 pm Wednesday March 14.

T. J. Maitland, American Telephone and Telegraph Co., New York and W. A. Sinclair, Detroit Edison Co., Detroit are chairmen.

The symposium is concurrent with the Chemical Industry Symposium and Pipe Line Group Discussions.

Abstracts of papers follow:

Field Laboratory Testing of Wrappings for Buried Structures by H. M. Clayton, Memphis Light, Gas and Water Div., Memphis, Tenn.

To determine the preferred type of tape for insulating gas pipe and fittings at the junction of coated services and coated mains, tests were made on test samples of tape applied to pipe and fittings and then submerged in a water bath having a resistivity of 2000 ohms per cubic centimeter. Direct current voltage, simulating cathodic protection, was applied between the water and the pipe except that the voltage was raised at intervals, above a normal cathodic protection voltage, for the purpose of ageing, to a maximum of 2.5 volts between the pipe and copper-copper sulfate electrode.

The following observations were made weekly: The current flow between the pipe and the water, the voltage to a copper-copper sulfate electrode and the applied direct current voltage was read and recorded before and after each adjustment. Water resistivity was measured at each weekly observation.

In addition to the above, the weight of the water absorbed by the sample during the test was determined.

In this paper a general discussion of the details of the test and conclusions drawn therefrom are given.

●

Corrosion of Lead Sheathed Power Cables in Concrete Tunnels by R. I. Perry, Commonwealth Edison Company, Chicago.

The Commonwealth Edison Company has experienced an appreciable amount of corrosion on the lead sheaths of underground power cables where they are located in concrete tunnels. The corrosion occurred at several locations in a metropolitan city where the lead sheathed cables were installed in continuous, precast concrete ducts and in ducts of other non-metallic materials encased in concrete and placed in concrete tunnels under waterways. Tests indicated that the corrosion on the lead sheathed cables was due to calcium hydroxide from incompletely cured concrete.

Typical chemical analyses are shown of water from the continuous conduits. The sheath voltages and water conditions under which these cables operated are given and the methods employed to reduce the concentrations of calcium hydroxide in the continuous conduits are described. The pH values and concentrations of calcium hydroxide are shown for the water in the conduits in two tunnels prior to and after corrective measures were taken.

The methods now used by this company to cure concrete in tunnels before lead sheathed power cables are installed are also described. A brief description is given of the prelubrication of continuous tunnel ducts before pulling in large cables and of the application of pulling grease to the cables at the time of installation for the prevention of corrosion.

●

Testing Methods and Corrosion Control Measures for Buried Telephone Cables by Daniel R. Werner, American Tel. & Tel. Co., Kansas City, Missouri.

Most of the thousands of miles of buried telephone cable installed by the Bell System has been placed within the past 10 to 15 years. Although relatively few serious corrosion troubles have been experienced on these cables to date, investigations have indicated that damage due to corrosion on this type of plant may be expected to increase unless special mitigative measures are employed.

The number of miles of cable involved has made it desirable for those in charge of corrosion work to develop special layout records which will serve as a base for recording the results of field data such as: potential of cable to reference electrodes, sheath current flow measurements, location of corrosion troubles, of remedial measures and of other structures which might influence the corrosion problems, etc. One such record developed by the author and its use is described.

The difficulty involved in obtaining access to buried cable at the frequent intervals desirable for measurement of current flow on the cable sheath has led to consideration of other means of testing to more precisely locate areas of current loss and the amount of current discharged to the soil. Testing methods now under field trial by the author are discussed.

Utilization of data obtained by the above methods to determine the probable life of a cable from a corrosion standpoint and for balancing the estimated cost of remedial measures for an expected cable life against the cost of replacing the cable at some future date are also described.

●

Corrosion Control Equipment for Underground Cables in Conduit in a Stray Current Metropolitan Area by Edward P. Teale, American Telephone & Telegraph Co., Washington, D. C.

For many years prior to 1940 several miles of a main conduit route in a metropolitan area containing bare lead sheath intercity and exchange telephone cables were protected satisfactorily from stray current corrosion by a single drainage wire. This protection consisted of a 700,000 cm aerial wire connected from the cables at one location to the negative bus of the DC railway generat-

(Continued on Page 106)

Clayton

Perry

Werner

ABOUT the AUTHORS

HENRY M. CLAYTON—He is a member of AIEE, NACE and NAPE and a registered engineer of the state of Tennessee. He organized and has directed the Corrosion Prevention Department of the Memphis Light, Gas and Water Division since 1950. A student of electrical engineering at Texas A & M, he served in the infantry in World War I. He was employed successively in various engineering capacities by Texas Power and Light Company, Little Rock Railway Electric Company, Little Rock, Ark.; Arkansas Central Power Company, Memphis Power and Light Company, Memphis, Tenn. Since 1939 he was standardization engineer for the Memphis Light, Gas and Water Division.

R. I. PERRY—A senior engineer with Commonwealth Edison Company of Chicago, Ill., he has been employed by that company for the past 29 years. During that time he has been actively engaged in mitigation of corrosion of his company's equipment. He has a BS in electrical engineering, is a registered professional engineer in the state of Illinois and a member of NACE.

DANIEL R. WERNER—He is in charge of cable corrosion control engineering, Western Area, American Telephone and Telegraph Co., Kansas City, Mo. His work on electrolysis control goes back to 1934. He is an engineering graduate of Rose Polytechnic Institute, Terre Haute, Ind.

POWER AND COMMUNICATIONS

Field Laboratory Testing of Wrappings for Buried Structures by H. M. Clayton, Memphis Light, Gas and Water Div., Memphis, Tenn.

Corrosion of Lead Sheathed Power Cables in Concrete Tunnels by R. I. Perry, Commonwealth Edison Company, Chicago, Illinois.

Testing Methods and Corrosion Control Measures for Buried Telephone Cables by D. R. Werner, American Telephone and Telegraph Company, Kansas City, Missouri.

Corrosion Control Equipment for Underground Cables in Conduit in a Stray Current Metropolitan Area by E. P. Teale, American Telephone and Telegraph Co., Washington, D. C.

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**Patents Applied For*

Practical Cathodic Protection Problems Covered

Criteria, Magnesium Anode Efficiency Study Are Included

Although two of the papers in the Cathodic Protection Symposium pertain to problems associated with lead sheathed cables, important data are given in two others on a method of protecting radiant heating piping and theoretical studies on Magnesium anode efficiencies. The symposium begins at 9 am Tuesday, March 15.

A. L. Ayres, New Jersey Bell Telephone Co., Newark and C. R. Johnson, Port of New York Authority, are chairmen.

The symposium is concurrent with the Plastics and Refinery Industry symposia.

Abstracts of papers follow:

Cathodic Protection of Radiant Heating Pipes by L. C. Wasson, A. O. Smith Corp., Milwaukee.

In trying to apply cathodic protection to radiant heating pipes, it was not possible to provide protection from an external ground bed so distribution anodes were installed through a concrete floor. Because some 500 anode clusters were installed in a space 300 x 1200 feet some unusual techniques of application had to be developed to make the installation feasible. These techniques, along with the reasoning that led to their use are described. Also mentioned are some of the problems encountered in trying to determine if and when complete protection of the system was obtained.

•

Lead Cable Sheath Corrosion Under Cathodic Protection Conditions by W. H. Bruckner and R. M. Wainwright, University of Illinois, Urbana.

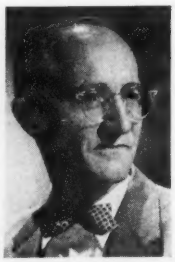
Numerous tests have been made in the Cathodic Protection Research Laboratory at the University of Illinois with cathodes of lead cable sheath in solutions of single chlorides or chloride mixtures including Na, K, Ca and Mg chlorides. A number of tests have also been made in solutions which not only contained chlorides but were made strongly alkaline (pH = 12.4). Some of the runs were made in cells containing the aqueous solutions of chlorides or chlorides and alkali while other tests were made with the lead cable sheath cathodes in contact with soil saturated with the various solutions. The results from all of these tests indicated that no corrosion of the cable sheath occurred in any of these environments as long as the cathode was receiving protective current. This conclusion applies to protective currents in the range of 50 to 2000 ma/ft² which have so far been studied. Data established by the tests made so far were considered to be negative because they did not reproduce the corrosion experienced in the field. However, the data should rather be considered as highly positive since they establish the excellence of cathodic protection methods in combatting corrosion even in environments having high alkalinity.

Recent data obtained by the cathodic protection laboratory show that corrosion and pitting of lead cable sheath may occur when the protective current is interrupted. The cathode products of previous cathodic protection constitute an environment for potentially serious corrosion at any time that the protective current ceases to flow to any part of the lead cable sheath. In service the flow of protective current may decrease or cease due to various circumstances which may be listed as: a) Cathode films of high resistance formed by Ca or Mg oxides. b) Removal of soil moisture or duct water which may vary seasonally. c) More highly conducting path for cathodic protection current formed by contamination with de-icing salts somewhere else in the circuit. d) Daily and seasonal variation of stray currents.

On the above basis it is seen that when protective current ceases for any of the reasons cited the most corrosive condition would exist where prior to current interruption the cable sheath had received the largest protective current. The term cathodic corrosion is therefore considered to be a misnomer and should be replaced in the literature by the more accurate description *"corrosion by cathodic products."*

It is generally recognized in the field that lead cable sheath failure is most prevalent where the environment has a high concentration of de-icing salts and the cable sheath is highly negative to ground. A more important factor which has not received recognition is the length of time during which such a system operates without protective current because the highly negative condition produces large amount of alkali as long as the high protective current flows. The alkaline environment of a protected lead cable sheath is apparently corrosive only when the sheath loses its negative potential due to the absence of protective current. In fact selective corrosion such as gives rise to pit formation may be enhanced by non-uniform dissipation of the polarization potentials produced by previous cathodic protection as was indicated from inter-

(Continued on Page 105)



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Weast

CATHODIC PROTECTION

Cathodic Protection of Radiant Heating Piping by L. C. Wasson, A. O. Smith Corporation, Milwaukee, Wisconsin.

Lead Cable Sheath Corrosion Under Cathodic Protection Conditons by W. H. Bruckner and R. M. Wainwright, University of Illinois, Urbana, Ill.

Potentials as the Criteria for Cathodic Protection of Underground Lead Cable Sheath by K. G. Compton, Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.

Current Efficiency of Magnesium Anodes Used for Cathodic Protection by R. C. Weast, Case Institute of Technology, Cleveland, Ohio.

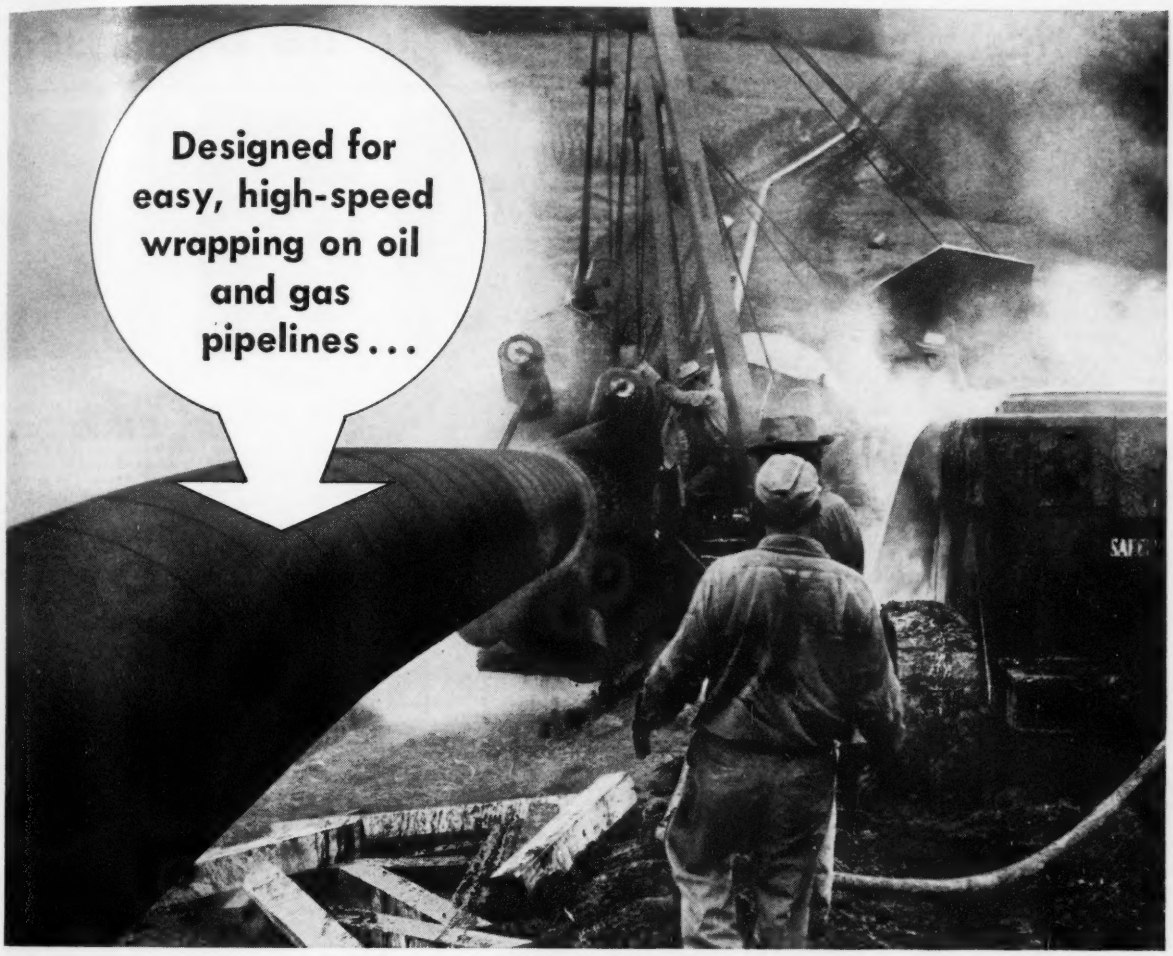
ABOUT the AUTHORS

L. C. WASSON—He is director of Project Laboratory B in the Research and Development Division of A. O. Smith Corp. and since he joined the company in 1933 he has been active in research and development in hydraulic, mechanical and electrical engineering. In 1951 he organized Project Laboratory B to work with cathodic protection and associated phenomena. He has a BSEE degree from University of Arkansas.

WALTER H. BRUCKNER—He is a research associate professor of electrical and metallurgical engineering at the University of Illinois and is technical director of the Cathodic Protection Laboratory there. Prior to coming to the university in 1938 he was on the research staffs of the Naval Research Laboratory, American Smelting and Refining Co. and Crucible Steel Co. His publications have been in physical metallurgy, fatigue of metals, welding, brittle fracture of steel and corrosion. He is author of a book "Metallurgy of Welding," Pitman, 1954. Mr. Bruckner is a member of AIME, ASM, AWS, NACE and Sigma Xi.

RAY M. WAINWRIGHT—Associate professor of electrical engineering at University of Illinois, Urbana, he has a BS in EE from Montana State College and an MS from University of Illinois. He has worked as electrical engineer for power companies on corrosion problems and has taught courses in electrical circuit analysis and engineering economics at University of Illinois since 1946. He is active in technical affairs of AIEE and NACE and has been responsible for short courses on cathodic protection given in recent years at his school. He has published many papers on engineering economics, including cathodic protection.

ROBERT C. WEAST—Professor of Chemistry at Chase Institute of Technology, Cleveland, he has a PhD in chemistry from University of Illinois (1943). He has been a consultant, researcher and teacher, conducting studies of galvanic corrosion in hot water storage tanks, among other things. He has been active in NACE affairs for several years.



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Plastics Engineering Data Will Be Discussed

Performance Data Will Be Stressed In Four Papers

New performance data valuable to the engineer working with plastic materials will be given in four of the five papers scheduled during the 5-paper Plastics Symposium which begins at 9 am Thursday March 15. The introduction will serve to orient the listener into the extensive information to follow.

R. B. Seymour, Loven Chemical Co. of California, Newhall and G. Heinemann, Columbia-Southern Chemical Corp., Corpus Christi are chairmen.

The symposium is concurrent with the Cathodic Protection and Refinery Industry symposia.

Available abstracts follow:

Properties and Performance of Reinforced Polyester Plastics in the Chemical Industry by R. E. Gackenbach and D. G. Estey, American Cyanamid Company, Bound Brook, New Jersey. The use of reinforced polyester resins as a material of construction in the chemical industry is relatively new and is one which warrants periodic review. This paper will discuss 1) some of the basic properties of polyesters which must be considered by designers and fabricators, and 2) some examples of actual field installations. This detailed information is given so that other end

(Continued on Page 108)

Estey

Fenner

Gackenbach

Seymour

Whittier

ABOUT the AUTHORS

DONALD G. ESTEY—Presently Assistant Product Supervisor, Polyester Resins, American Cyanamid Company, New York, N. Y., he has a BS in chemical engineering, Queen's University, Ontario, Canada. Following employment with International Nickel Company in Canada he was for 10 years with Vacuum Chemical Corporation in production and sales of phenolic resins and for three years was production superintendent at American Cyanamid's Bridgeville, Pa. polyester resins plant. He was assigned to the Plastics and Resins Division marketing group in New York in 1953.

OTTO H. FENNER—Mr. Fenner currently is engaged in operations research at the John F. Queeny Plant of Monsanto Chemical Company in St. Louis. Since 1934 when he joined Monsanto he has worked as production supervisor, area supervisor, project engineer, supervising engineer. Included in his NACE activities are organization of the Greater St. Louis Section in 1948, being chairman of the St. Louis Section, co-editor of the St. Louis Section monthly paper "Corrosion Topics," chairmanship of T-5D-7 on Engineering Design of Plastic Materials of Construction for the Chemical Industry. He also is a member of NACE T-6A committee on organic coatings and president of St. Louis Professional Chapter of Alpha Chi Sigma and of ACS. He has an AB in organic chemistry from Washington University, St. Louis.

R. E. GACKENBACH—Associated with Organic Chemicals Division of American Cyanamid Company as divisional materials engineer, he devotes full time to evaluation, selection and specification of materials of construction. His recommendations cover design, fabrication and installation of process equipment. He has a BS in metalurgical engineering from Lehigh University and is active in ASM and NACE. He is chairman of NACE T-5D-6 on Organic Chemicals.

RAYMOND B. SEYMOUR—For more than 20 years he has been occupied with research and application of plastic materials for corrosion control purposes. He is now president of Loven Chemical Company, Newhall, Cal. and formerly was president of Atlas Mineral Products Co., Mertztown, Pa. In demand as a speaker on corrosion control matters related to plastics, he has appeared in many parts of the United States before engineering groups. His publications on plastics materials are voluminous, including three books, Plastics in Building, Corrosion Handbook and Plastics for Corrosion Resistant Applications.

ROBERT P. WHITTIER—As project engineer for Monsanto Chemical Company, Plastics Division, he is active in matters connected with the company's Plastic House of Tomorrow, a prototype designed for experimentation and evaluation of materials in the residential construction field. He is a member of the ASCE, the Building Research Institute and the Engineering Society of Western Massachusetts.

PLASTICS

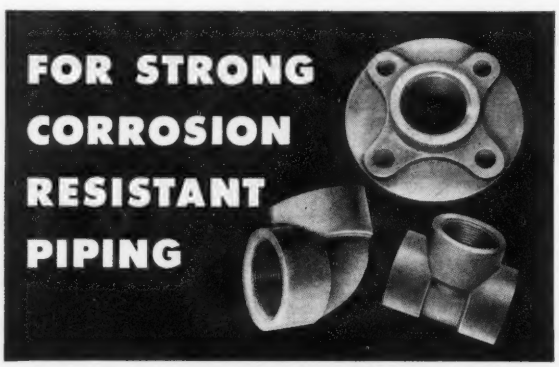
Introduction, R. B. Seymour, Loven Chemical Company of California, Newhall, California.

Properties and Performance of Thermoplastics in American Industry by J. F. Malone, B. F. Goodrich Chemical Co., Cleveland, Ohio and John McBride, Owens-Corning Fiberglass Corp., New York, N. Y.

Properties and Performance of Reinforced Polyester Plastics in the Chemical Industry by R. E. Gackenbach and D. G. Estey, American Cyanamid Company, Bound Brook, New Jersey.

Impervious Graphite as an Engineering Material by W. W. Palmquist, National Carbon Company, Cleveland, Ohio.

Design and Engineering of Plastic Materials of Construction by R. P. Whittier and O. H. Fenner, Monsanto Chemical Co., St. Louis, Mo.



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Significant High Temperature Data Are Covered

Important Papers On Reaction of Metals Scheduled

Considerable detailed information on high temperature corrosion reactions of metals is included in the 3-paper Elevated Temperature Symposium which begin at 2 pm Thursday March 15. Atomic energy, nickel-chromium steels and role of minor elements will be covered.

C. C. Harvey, Ethyl Corp., Baton Rouge, La. and W. D. Manly, Oak Ridge National Laboratory, Oak Ridge are chairmen.

The symposium is concurrent with the Protective Coatings and Worldwide Developments in Corrosion symposia.

Abstracts of papers follow:

Resistance of Metals and Alloys to Corrosion by Fused Sodium Hydroxide by G. Pedro Smith, Mark E. Steidlitz and Eugene E. Hoffman, Metallurgy Division, Oak Ridge National Laboratory.

This paper describes the results of a series of investigations of the resistance of metals and alloys to corrosion by fused anhydrous sodium hydroxide at temperatures up to 815 C. Metallographic studies were made of the corrosion products and of the effects of corrosion on the microstructures of alloys. Several unusual corrosion phenomena were encountered. Measurements were made of the mass transfer of metal induced by thermal gradients both in elementary metal systems and in alloy systems. Some of the theories which have been proposed to account for corrosion phenomena in fused hydroxide media are discussed.

•

Structure of Oxide Scales on Nickel-Chromium Steels by H. J. Yearian, H. E. Boren and R. E. Warr, Physics Department, Purdue University, Lafayette, Indiana.

Gulbransen

Hoffman

Smith

Steidlitz

Yearian

The structure of the scales formed on Ni-Cr steels ranging from 8 to 80 percent Ni and 0 to 26 percent Cr when oxidized for 100 hours in air at temperatures from 1600 to 2200 F have been investigated by X-ray diffraction methods. The scales are of two types, A′ and B′, which are analogous to and show the same correlations with attack rate as the A and B scales, respectively, on chromium steels.

The major constituent of the more protective A′ scale is Cr_2O_3, as in the A scale, and the similarity also applies with respect to the occurrence of $MnCr_2O_4$. A′ scale differs from A in two respects,

(Continued on Page 109)

ABOUT the AUTHORS

H. E. BOREN—He is now with Stanolind Research Laboratory, Tulsa. He has a BS in chemical engineering, 1945, and an MS in physics, 1950, both from Purdue University.

EARL A. GULBRANSEN—For the past 15 years he has worked in the high temperature oxidation and corrosion fields at Westinghouse Research Laboratories, where he is now advisory chemist. He was a post-doctoral National Research Council fellow and research associate at the University of California in Berkeley. In 1936 he accepted a position as instructor in chemistry and chemical engineerging at Tufts College, Medford, Mass. He has a BS in chemical engineering, State College of Washington (1931) and as graduate assistant at the University of Pittsburgh in 1931-34 he obtained a PhD in physical chemistry. In 1952 he was given the NACE Whitney Award.

EUGENE E. HOFFMAN—He has a 1951 BS from University of Notre Dame and joined the staff of Metallurgy Division, Oak Ridge National Laboratory after graduation. He is now in charge of the high temperature corrosion testing group.

G. PEDRO SMITH—He is in charge of the high temperature corrosion chemistry group of the Metallurgy Division, Oak Ridge National Laboratory. He has a PhD in physical chemistry from University of Virginia (1950).

MARK E. STEIDLITZ—His research since graduation from University of Rochester with a BA in chemistry and with an MA in chemistry from University of Buffalo has been on radiation chemistry of fluorides and inorganic bases, and more recently, on the chemistry of liquids at high temperatures.

H. J. YEARIAN—Since 1938 Dr. Yearian has been professor of physics, Purdue University. He holds a BS and MS in physics, 1927, 1929, University of Oregon, and a PhD in physics, 1934, Purdue University. He was a National Research Fellow in 1936-38. His principal interests are semiconductors, X-ray and electron diffraction and electron microscopy.

R. E. WARR—Now with the National Bureau of Standards, Washington, D. C., he has a BS from Fisk University, 1949 and an MS in physics, 1951, Purdue University.

ELEVATED TEMPERATURE

Resistance of Metals and Alloys to Corrosion by Fused Sodium Hydroxide by G. P. Smith, M. E. Steidlitz and E. E. Hoffman, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Structure of Oxide Scales on Nickel-Chromium Steels by H. J. Yearian, H. E. Boren and R. E. Warr, Physics Department, Purdue University, Lafayette, Indiana.

Role of Minor Elemets in the Oxidation of Heater Alloys of the Nickel-Chromium Series by E. A. Gulbransen, Westinghouse Research Laboratories, Churchill Borough, Pennsylvania.

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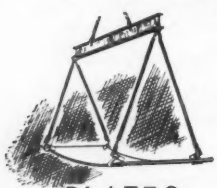

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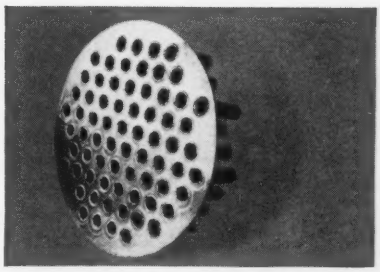
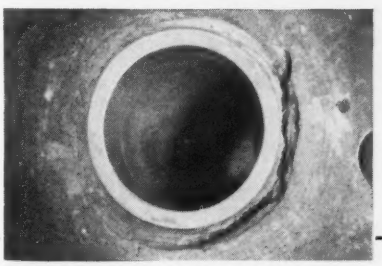


HOT NITRIC ACID at pressures of 300 psi took a high toll of stainless-steel condenser tubes at a Du Pont plant—until this titanium "top-hat" was installed. Fabricated entirely of titanium, it provides a protective sleeve inside the top 3 inches of the condenser tubes. The unretouched photo shows the clean, uncorroded appearance of the "top-hat" after 14 months' continuous service. The titanium tube sheet, tubes and welds have essentially the same appearance as when installed . . . show evidence of being able to serve indefinitely.



HIGH-VELOCITY STEAM and biting hydrochloric acid were cutting the service life of cast-iron steam diffusers to less than 3 months at a Du Pont Pigments plant. Bronze and corrosion-resistant alloys were tried, without improvement. Then a diffuser fabricated from titanium was installed. This proved to be the answer. The photo shows the condition of the titanium diffuser after 2 years' service—a period ten times the average life of other diffusers. Compare the uncorroded appearance of the titanium diffuser with the cast-iron flange, which shows severe acid attack.

A partial list of other environments where TITANIUM offers unmatched corrosion resistance . . .

CORROSIVE CHEMICALS	CONDITIONS	POSSIBLE APPLICATIONS
Ferric Chloride	0-30% at 100° C.	Process piping
Sodium Chloride	All Conc. at 100° C.	Kettles, heat exchangers
Chlorine-Saturated Water	Room Temperature	Proportioning equipment
Wet Chlorine Gas	75° C.	Recovery equipment, electrolytic cells
Chromic Acid	10% and boiling	Plating equipment
Sulphuric-Nitric Acid Mixture	40% sulphuric, 60% nitric at 35° C.	Acid heaters, nitrators, auxiliaries
Calcium Hypochlorite	6%-35° C.	Filter presses, processing equipment
Zinc Chloride	20%-100° C.	Coils, pans, evaporators

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If you're looking for a way to improve your product . . . or cut production and maintenance costs by extending the service life of essential equipment . . . it may pay you to investigate titanium. As a pioneer *supplier* of titanium sponge, Du Pont has the experience to offer you expert technical help with your evaluation tests . . . can put you in touch with manufacturers best equipped to work with you on your particular product or application. Considerable fabricating know-how and a wide variety of mill shapes are available now to help you use titanium to solve your corrosion problems. For more detailed information on titanium, just check the coupon below, or write: E. I. du Pont de Nemours & Co. (Inc.), Pigments Department, Wilmington 98, Delaware.

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Coatings Symposium Scans Sprayed Metals, Zinc

Work Measurement Criteria Weighed; Zinc Reviewed

Three papers are to be given in the Protective Coatings Symposium beginning at 2 pm Thursday, March 15. One paper discusses sprayed metals and plastic coatings systems, another gives experience information on zinc coatings and a third details a plan for arriving at work measurement criteria relating to painting operations.

W. P. Cathcart, Tank Lining Corp., Pittsburgh and L. S. Van Delinder, Carbide and Carbon Chemicals Corp., South Charleston, West Virginia are chairmen.

The symposium is concurrent with the Elevated Temperature and World Wide Developments in Corrosion symposia.

Abstracts follow:

Sprayed Metals Plus Plastics by Walter B. Meyer, St. Louis Metallizing Company, St. Louis, Missouri.

Service records of metal sprayed coatings that were applied in the early 1930's now are serving to indicate the measure of protection afforded.

Modern metal spraying equipment centers around the wire consuming units as opposed to powder spray units. Metal of any analysis that can be obtained in wire or rod form can be deposited by propelling it through the oxy-fuel gas jets of the unit. As the wire is rendered molten, the liquid metal is divided into finely divided molten spheres, each in an oxide envelope, which are driven on to a suitably prepared surface where the particles rapidly solidify. This method of deposition results in a laminar deposit with peculiar characteristics. Because of the oxide cementation of molten particle to molten particle and because of the flake-like structure, such deposits behave very much in the manner of a cast structure.

Base metals to which a corrosion resistant coating of sprayed metal are to be attached must be prepared previously by pressure blast cleaning. Particle size, abrasive analysis, sharpness of the particle, air pressure, cleanliness of the air supply and the angle of impingement are all of great importance.

Chemical composition of the abrasive material and its possible contaminating effect upon the surface to be coated is of utmost importance.

Slides of various types of abrasive particles and the resulting blasted surfaces will be shown.

Until recently, sprayed metal coatings for resistance to corrosion were limited to those metals anodic to iron and steel. For practical reasons, zinc and aluminum were the sacrificial metals usually sprayed. Though porous, they afford protection by electro-chemical action.

In the past seven years overcoating of sprayed zinc and aluminum metal coatings with vinyl plastic solutions, chlorinated rubbers and silicone solutions has resulted in longer life and lower cost. These materials minimize porosity and slow the rate at which the zinc or aluminum coating is sacrificed.

Formerly metals below iron or steel in the electromotive series were not suitable for corrosion resistant coatings when deposited by the metallizing process but special procedures have been developed whereby sprayed deposits of nickel, Monel, stainless steels, Hastelloy alloys and others can be rendered nonporous by impregnating their porous structures with various organic materials. Impregnating materials can be chosen from among vinyl plastics, chlorinated rubbers, epoxy resin formulations, liquid Neoprene, Gilsonite mastics, catalytically cured phenols, heat cured phenols, furane-phenol-epon combinations and many others. Impregnating procedures are critical and cathodic metals plus organic coating systems must be used judiciously and only after thorough testing.

Examples of successes and failures of the combination coatings will be cited.

•

Work Measurement As Applied to Industrial Painting by B. C. Wright, Carbide and Carbon Chemicals Company, Texas City, Texas.

Production of paint crews vary with material, location, weather, morale and other factors. Consequently, it is difficult to know when full day's work is obtained. This paper explains the application of three types of work measurement: Daily square footage and man hour reports, motion picture studies and work sampling. Results are included for a particular job, but sufficient details are given to permit the reader to apply work measurement on his jobs and thereby increase production.

•

Control of Corrosion With Zinc Coatings by J. L. Kimberley, American Zinc Institute, New York.

This paper covers briefly, an outline of the history of the uses of metallic zinc and zinc coatings to control corrosion, and the basic theory under which zinc is protective to steel. Methods of application including hot dip and electro-galvanizing, metallizing, Sherardizing and painting are outlined and discussed. Relative merits and weaknesses of zinc coats are indicated as well as general statements covering the fields of usefulness, case histories and overall considerations, including economics.

Kimberley

Meyer

Wright

ABOUT the AUTHORS

WALTER B. MEYER—President of St. Louis Metallizing Company, St. Louis, Mo. he has been in the metal spraying field since 1935. He formerly was with Metallizing Engineering Company as sales and service engineer and as Midwestern Branch Manager. In 1939 he joined Nooter Corporation as manager of its metallizing division leaving to assume his present position. During World War II he was engaged by the War Department in installing equipment for and training personnel in the China-Burma-India and Mediterranean theaters in metallizing. He is a member of NACE, AWS, Society of Plastic Engineers and Engineers' Club of St. Louis. He formerly was chairman of the National Metallizing Committee of AWS.

B. C. WRIGHT—He presently is head of the Coating Section and Industrial Engineering Section as maintenance engineer with Carbide and Carbon Chemicals Co., Texas City. He has a BS in mechanical engineering from Purdue University and joined Carbide upon graduation in 1952. He is a member of NACE.

J. L. KIMBERLEY—Executive vice-president of the American Zinc Institute, from 1944 to 1955 he was sales manager of Continuous Cast Alloy Division of American Smelting & Refining Co. His other experience includes service on the War Production Board, in U. S. Navy and as metallurgist with Scovill Manufacturing Co., Waterbury, Con. He has a BS in mechanical engineering from Yale (1928) and an MS in metallurgy (1930).

PROTECTIVE COATINGS

Sprayed Metals Plus Plastic Coatings by W. B. Meyer, St. Louis Metallizing Co., St. Louis, Mo.

Work Measurement as Applied to Industrial Painting by B. C. Wright, Carbide and Carbon Chemicals Corp., Texas City, Texas.

The Control of Corrosion with Zinc Coatings by J. L. Kimberley, American Zinc Institute, Inc., New York, N. Y.

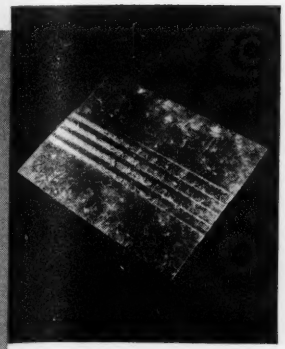
Complex Problems—

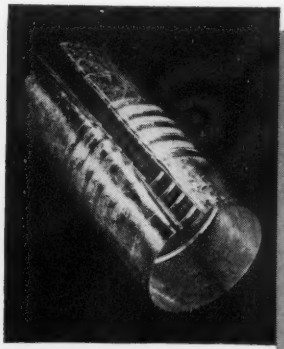
(Continued From Page 92)

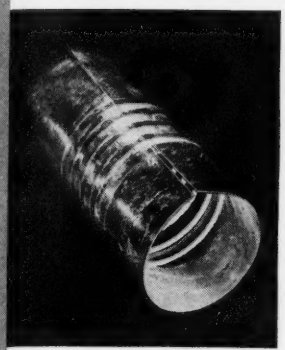
Containers byA. R. Willey, Research Division, American Can Co., Barrington, Ill. and J. L. Krickl, Technical Service Division, American Can Co., Maywood, Ill.

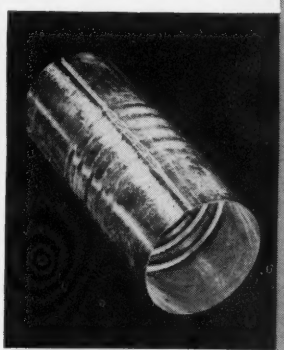
Two easily performed laboratory tests have been developed which give results correlating with internal corrosion performance of plant electrolytic tinplate containers. One, the "rate of pickling" test, measures a permanent surface property of the steel arising in the annealing operation. The other, the "iron solution" test, measures the effect of certain factors governing the nature of the steel surface prior to electrotinning and to some extent the effect of the plating operation itself.

Tin plate manufacturers have used these tests as guides in improving the corrosion resistance of their product. The described tests, however, are not entirely adequate to account for all the existing variations in corrosion performance believed to be related to steel surface characteristics. Additional work is required.



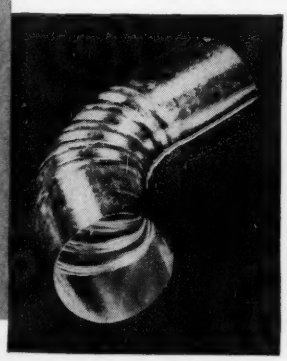


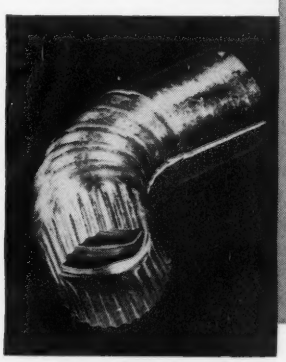




AN EXAMPLE: Previously made of terne plate and hand-dipped after fabrication, this finished conductor pipe elbow is now produced direct from flat, galvanized stock in six operations, *involving 180° interlocking bends, without coating failure.* This effects substantial savings in manufacture.

Photos courtesy of WHEELING STEEL CORP.





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Authors from Abroad to Give Three Discussions

International Aspects Of Session Bolstered By Three Papers

Three papers by authors from abroad bolster the international aspects of the corrosion control problem in the World-Wide Developments in Corrosion Symposium beginning at 2 pm Thursday, March 15. These papers cover novel information on corrosion by geothermal steam, cathodic protection measures applied to a vast irrigation pipe system and a theoretical discussion of corrosion processes.

This symposium is concurrent with the Elevated Temperature and Protective Coatings symposia.

Abstracts of papers follow:

Corrosion by Low-Pressure Geothermal Steam by T. Marshall and A. J. Hugill, Dominion Laboratory, Department of Scientific and Industrial Research, Wellington, New Zealand.

Corrosion tests in geothermal steam contaminated with chlorides, hydrogen sulfide and carbon dioxide are described, detailed results being given for a range of common engineering alloys.

Most engineering alloys proved moderately susceptible to steam corrosion. Titanium and austenitic stainless steels (especially molybdenum-bearing varieties) were highly resistant. Stress-corrosion cracking occurred in hardened 13 Cr stainless steel, hardened low-alloy steels, one grade of austenitic stainless steel and aluminium bronze.

Physical and chemical factors influencing corrosion by the geothermal steam are discussed.

•

Application of Cathodic Protection in Israel by D. Spector, Tel Aviv, Israel.

Inspired by the rapid progress achieved in the field of cathodic protection in the U. S. A. application of this technique was begun almost 10 years ago.

Extensive rehabilitation programs which followed the war of independence in 1949 has brought about the construction of country-wide water works. Close to 500,000 tons of steel piping constitute the present water mains and progress continues.

Israel is situated in a sub-tropical zone characterized by a hot and dry climate. For 8 months there is no rain at all. As a result irrigation is essential for obtaining good crops. Large farms are widespread and their irrigation networks are of a peculiar nature. Soil resistivity ranges from 350 ohm/cm and up with 1000 ohm/cm average. Water resistivity is about 2000 ohm/cm although resistivity of 250 ohm/cm is often encountered in some wells. Due to local conditions corrosion is causing heavy damage to such networks. Cathodic protection has been extremely efficient in eliminating leaks in such cases.

Cathodic protection also has been applied to fishing vessels and other marine craft which have resulted in complete protection against corrosion. Marine fouling has been found completely absent on hulls maintained at a potential of about 1.0 volt to copper copper-sulfate electrode. Electrolytic descaling of ships hulls is being applied successfully based on a method developed and patented locally.

Domestic electric boilers are used extensively and their average lifetime has been found to be 3 years. Cathodic protection is now widely used with complete success.

•

Corrosion by Differential Aeration and Passivity of Zinc by E. Bianchi, Politecnico di, Milano, Italy.

Corrosion by differential aeration of zinc has been investigated in different conditions of aeration, pH, duration of test. Results show that the condition of attack by differential aeration is realized only when the zinc is passive on the more aerated area, on which oxygen is reduced. Local corrosion processes take place on both anodic and cathodic areas, superimposed to the main process. In buffered solutions the distribution of the attack is changed and the corrosion is localized at the water line.

Hugill

Marshall

Spector

ABOUT the AUTHORS

T. MARSHALL—Metallurgist as Dominion Laboratory, Dept. of Industrial and Scientific Research, New Zealand, he holds bachelor degrees in engineering and science from Otago University, is an associate of the Otago School of Mines and Metallurgy, Associate of the Institution of Metallurgists and a junior member of the AIME. His principal work is in corrosion research and technology.

A. J. HUGILL—He is chemical engineer at Dominion Laboratory, Dept. of Scientific and Industrial Research, New Zealand. He has a BSc degree from Victoria University College and a PhD from Birmingham, England. He spent several years in England in scientific work before returning to New Zealand to work on the geothermal project. He is now assistant manager of the Huntly Brick and Fireclay Co., Ltd.

D. SPECTOR—A graduate in electrical engineering of Manchester College of Technology, England in 1937 he now owns and manages an engineering firm doing cathodic protection work in Israel. He has been an active member of NACE. During the Israeli War of Independence he was head of the Technical Division of the Ministry of Defense Supply Dept. He is a member of NACE, AIEE and of the Association of Engineers and Architects in Israel, as well as chairman of its Corrosion Group.

WORLDWIDE DEVELOPMENTS

Corrosion by Low Pressure Geothermal Steam by T. Marshall and A. J. Hugill, Department of Scientific and Industrial Research, Wellington, New Zealand.

Applications of Cathodic Protection in Israel by D. Spector, Tel Aviv, Israel.

Corrosion by Differential Aeration and Passivity of Zinc by G. Bianchi, Laboratori di Elettrochimica, del Politecnico di Milano, Milan, Italy.

These concepts, and the hypotheses based upon them, are demonstrated and supported by examples drawn from purely chemical research as well as from corrosion experiments and experience.

•

Effects of Velocity on Corrosion by H. R. Copson, the International Nickel Co., Inc., New York.

Velocity can be a major factor in the corrosion of metals and like most factors influencing corrosion, its effects are varied and sometimes appear conflicting. An increase in the rate of movement of the environment past a metal part usually increases the corrosion by supplying the corrosives at a faster rate. The corrosives can reach the metal surface more readily because the motion thins or removes quiescent layers at the metal surface. On the other hand uniform motion may be beneficial because it makes the exposure conditions more uniform and thus may prevent local attack and pitting. Some motion is definitely beneficial if inhibitors are present. In the extreme case, high velocity may induce passivity and stop all corrosion. The more damaging effects of velocity are often due to turbulence. The turbulence may set up differential aeration cells and metal ion cells which lead to rapid local attack. The turbulence may form anodic areas by eroding away thin protection films, in which case the attack is called erosion-corrosion. A high ratio of cathodic area to anodic area increases the rate of penetration in these cases. Velocity effects are different on different metals, and accordingly the galvanic behavior of couples may be changed greatly. Actual erosion of metal can be caused by very high velocities, particularly if solids are present. Related to velocity effects is the damage caused by cavitation-erosion. Examples are given illustrating all these types of attack.

Three Educational—

(Continued From Page 76)

fectiveness of a corrosion inhibitor should be predictable from molecular structure. For chemisorbed inhibitors the nature of the metal exerts a specific influence. All of these statements hold for organic inhibitors and for many inorganic inhibitors. Some inorganic inhibitors, however, are effective because they provide a precipitated barrier rather than an adsorbed barrier.

Practical Cathodic—

(Continued From Page 96)

mittent tests carried out in cells with NaCl and NaOH.

•

Potentials As the Criteria for Cathodic Protection of Underground Lead Cable Sheath by K. G. Compton, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

A report is made of the study of the static and dynamic potentials of lead cable sheath in 48 soils from various sections of the United States. Soils have been selected as representative of those actually in contact with cable sheaths. Anodic and cathodic polarization curves in representative soils, using a null bridge technique, are given to illustrate the potential changes accompanying corrosion and cathodic protection. Data indicate that significant corrosion may occur at potentials near the static potential of the lead sheath for that particular soil. To achieve cathodic protection it appears that the lead sheath should be polarized about 100 millivolts more negative than its static potential in the particular soil. In most soils this would require polarization to about 700 millivolts negative to the saturated copper—copper-sulfate electrode.

•

Current Efficiency of Magnesium Anodes Used for Cathodic Protection by R. C. Weast, Case Institute of Technology, Cleveland, Ohio.

Current efficiency may be defined as one hundred times the quantity of electric current which flows from an anode to the structure being protected divided by the quantity of electric current released by the anode during its corrosion. The current efficiency of magnesium anodes is usually considered to be 50 percent or less. This is based upon the assumption that the magnesium anode corrodes according to the equation

$$Mg \rightarrow Mg^{++} + 2e$$

Evidence is presented to indicate that magnesium does not corrode according to the above equation, but that it corrodes with only one electron being available to protect the pipe line or structure connected to the anode. Thus, the initial step in the corrosion of magnesium is

$$Mg \rightarrow Mg^{+} + 1e$$

This is followed by

$$Mg^{+} \rightarrow Mg^{++} + 1e$$

The latter occurs in solution so that the second electron removed from magnesium is not available for cathodic protection. This mechanism would account for certain observations made on corroding magnesium as the evolution of hydrogen from the apex of pits where it is believed the pits are anodes. The data which are presented to substantiate this mechanism are those obtained from electrical potential and current measurements and from polarization experiments.

•

NACE HAS NO COPIES OF CONFERENCE PAPERS

No copies of papers presented at the 12th Annual Conference are available from NACE. Authors of papers sometimes prepare preprint versions of their papers in which cases copies may be secured from authors. Persons interested in technical material presented are urged to consult CORROSION in which all papers approved by the NACE Editorial Review Subcommittee and the editor of CORROSION will be published as they are approved. Non-members of NACE may subscribe to CORROSION at rates indicated on the Contents Page of this issue.

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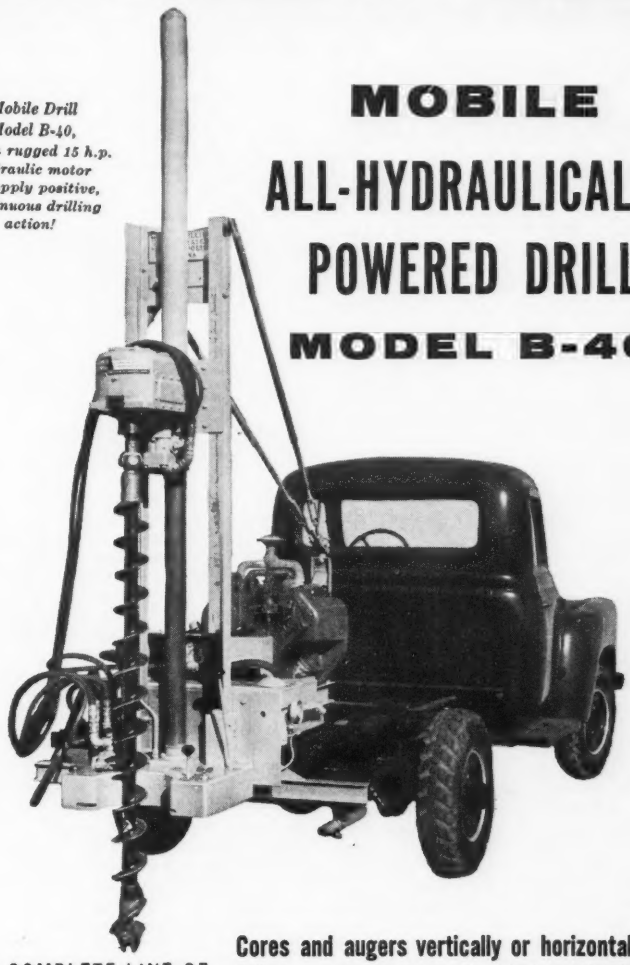

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Pipeliners to Have Two Discussion Sessions

Group Meetings and Round Table Are Planned at New York

Nine meetings of small groups during the Pipe Line Group Discussions program to be held beginning at 2 pm Wednesday, March 14 and the Pipe Line and Underground Corrosion Roundtable to be held beginning at 9 am Friday, March 16 are planned for pipe line people especially. These sessions give the pipeliners the opportunity to seek and exchange information on corrosion problems peculiar to their industry.

L. R. Sheppard, Shell Pipe Line Corp. and C. L. Woody, United Gas Corp., Houston are chairmen of the group discussions and L. B. Nelson, Shell Pipe Line Corp. and O. W. Wade, Transcontinental Gas Pipe Line Corp., Houston are chairmen of the round table.

These sessions are informal and unrehearsed and no record is made of proceedings so everyone may feel free to speak.

General Corrosion Round Table to be Held Mar. 16

The annual General Corrosion Round Table will be held beginning at 9 am Friday, March 16. This session, which annually attracts a large number of participants, has F. N. Alquist, Dow Chemical Company, Midland, Mich. and A. H. Roebuck, Continental Oil Co., Ponca City, Okla. as chairmen.

Sessions are unrehearsed and unrecorded. All topics are considered except those properly belonging to the underground and pipe line category.

Cables and Stray–

(Continued From Page 94)

ing station approximately 1000 feet distant.

During and following the war period there was a rapid expansion of all types of underground utilities throughout the immediate and surrounding areas. This so altered the subsurface network conditions that the efficiency of the former protection was diminished by over 50 percent.

Investigation indicated that in order to reestablish adequate protection by a single natural drainage connection, a wire of over 3,000,000 cm size would be required. Further investigation indicated that by utilizing natural drainage from two points on the conduit system, thus providing the equivalent of distributed drainage, the size of wire for a natural drainage connection could be reduced to only slightly less than 2,000,000 cm.

As the result of additional study it was decided to utilize a controlled type of rectifier employing two stages of magnetic amplification in order to: 1) reduce the requirement for such very large conductors, 2) to limit the possibility of adverse effects on other nearby structures and 3) to obtain the economies of operation possible with this type of equipment. The primary purposes of such equipment are to overcome the IR drop in the drainage conductor and to limit the drainage current to the minimum value required by the natural potential difference between cable and earth. Employment of this equipment permitted the use of a distributed drainage arrangement, utilizing the original drainage facilities for one branch and a much smaller wire for the second branch.

This paper describes the system in detail, discusses the results obtained and the problems encountered in adjusting the rectifier equipment to obtain the desired operating characteristics.

Refinery Corrosion–

(Continued From Page 80)

over the field thinning of paint in order to assure a uniform coating and adequate mil thickness. A card system has been established to maintain a permanent record of each tank coating applied. The cost per square foot is computed and analyzed for each year. The service life is then calculated from these cards and combined with the cost to give a more realistic figure in cost per square foot per year of life. Charts and graphs are included which show that although the costs of the program were slightly higher initially, the aims of the program are now being realized and a reduced cost of nearly $50,000 per year is anticipated.

•

How Richfield Tackled Hydrogen Blistering at Its New Fluid Catalitic Cracking Unit by B. W. Neumaier and C. M. Schillmoller, Richfield Oil Corp., Wilmington, Cal.

Richfield Oil Corporation is making an all-out effort to avoid low-temperature hydrogen attack at its new Wilmington, California Fluid Unit.

Most sulfides and a large portion of other acidic compounds, are removed early in the process stream. Hydrogen sulfide is absorbed in a diethanolamine solution ahead of the second-stage compressor and an extensive waterwash is applied at the main fractionator overhead and at the first-stage compressor aftercoolers.

Of the 134,000 lb. per day of corrosive constituents in the main fractionator overhead stream, only 12 percent reaches the gas plant. Additional protection is provided for the deethanizer and depropanizer overhead equipment by caustic washing and drying of the feed to these towers.

Two vulnerable locations are created: The tower and overhead equipment of the diethanolamine stripper and of the sour water reclaimer. Both are protected by a corrosion inhibitor; in addition, the feed to the water reclaimer is neutralized.

Polysulfide injection facilities have been kept on standby to protect the vessel walls of the fractionator overhead and first-stage compressor systems when required. Inhibitor injection facilities are available for additional protection in the absorber-demethanizer and in the debutanizer overhead equipment.

The method of monitoring hydrogen blistering control is described.

•

High Temperature Hydrogen Sulfide Corrosion in Thermofor Catalytic Reformers by E. B. Backensto and R. D. Drew, Socony Mobile Laboratories, Paulsboro, N. J.; R. W. Manuel, Socony Mobile Oil Co., New York and J. W. Sjoberg, Socony Mobil Laboratories.

High temperature hydrogen sulfide corrosion is a serious problem in commercial reforming units. Corrosion tests conducted in two Thermofor catalytic reformers, which handle widely different type stocks, have shown that carbon and low chrome steels commonly used for construction in the petroleum industry will not resist hydrogen sulfide attack under the high temperature conditions of the process. The commercial tests confirmed laboratory results which indicated that only the 18-8 chrome-nickel and higher alloys show good resistance to this type of corrosion.

In addition to proper selection of alloys, altering the environment by reducing hydrogen sulfide concentration and the use of aluminum coated steels have been successful in combating this type of corrosion.

Statistical Methods–

(Continued From Page 87)

requirements of proper surface preparation, proper coating selection and proper application. Application cost can be cut by using designs with less surface area, using tapes as auxiliary protection, applying coatings by the hot spray method and using high solids content paints with fewer coats.

This paper briefly reviews the requirements for obtaining long coating life and then follows with more detailed discussions of the methods for cutting the application cost.

•

Estimating for Maintenance Painting by Richard F. Williams, Construction and Maintenance Supervisor, and J. H. Cogshall, Corrosion Engineer, Pennsylvania Salt Manufacturing Co., Philadelphia.

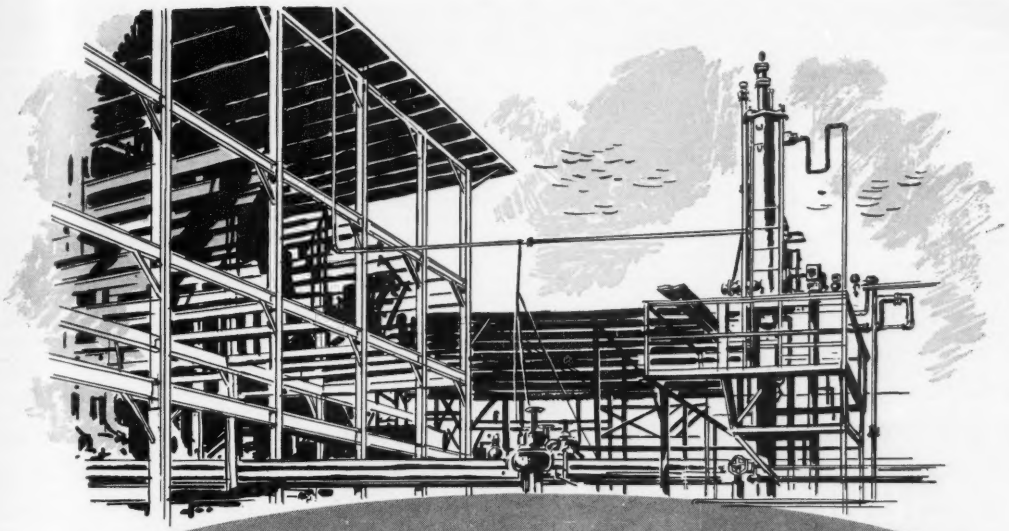
The need for and procedures for accurately estimating the cost of industrial maintenance painting are presented and discussed. A method proved by experience to give reasonably accurate results when used by estimators without intimate knowledge of painting technologies is presented. This method has proved also it will produce closely comparable cost predictions when used by different estimators.

•

Comparison of Alternatives by Capitalized Cost by F. C. Jelen, Allied Chemical & Dye Corp., Solvay Process Division, Syracuse, New York.

Capitalized cost offers a simple and exact method for comparing costs of alternatives on a common denominator basis. It allows for interest and can be used for a single article or expense, or for a whole plant. It accounts for differences in first cost, service life, operating ex-

(Continued on Page 108)



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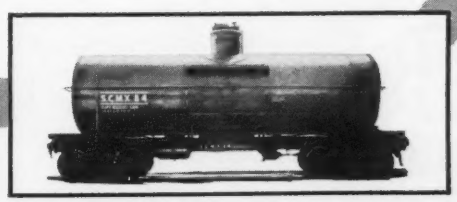

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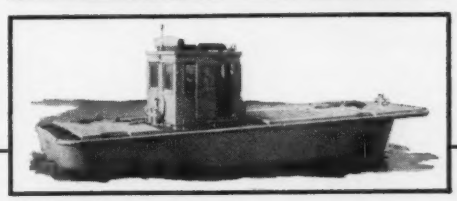

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Statistical Methods–

(Continued From Page 106)

pense, deferred costs, obsolescence and salvage value; but there is no limit to the items which can be considered. The calculations are readily made with the help of only a few tabulated factors. Capitalized cost is the present value of all costs for an indefinite time, but comparisons are correct for limited periods.

•

Application of the Statistical Theory of Extreme Values to the Analysis of Corrosion Pit Depth Data by P. M. Aziz, Aluminium Laboratories, Ltd., Kingston, Ont.

Pit depth distribution curves have been constructed for 2S aluminum immersed in tap water for time periods of 2 weeks, one, two, four and six months and one year. The distribution curves were found to consist of two superimposed curves; one, "J" shaped, results from pits which initiated and stifled within two weeks of immersion, whereas the other, a "bell" shaped curve, results from pits that initiated and continued to propagate. The "bell" shaped curve retains its shape and moves in the direction of increasing pit depth. After about two months the majority of these latter pits cease propagating, the mode of the bell shaped curve becomes stationary and only a small number of the deeper pits continue to propagate, the tail of the distribution curve lengthening with time.

The maximum pit depths obtained on each of replicate samples have been analyzed by the statistical theory of extreme values using the appropriate probability paper and have been found to fit the extreme value distribution.

$$\Phi_y = e^{-e^{-y}}$$

From this it has been shown that the maximum pit depth is linear in the logarithm of the exposed area thus providing a rational method of extrapolating pitting data obtained in the laboratory on small samples to large scale field installations. This fit of maximum pit depth data to the extreme value distribution also makes possible the extraction of more information from a limited number of pit depths than has been heretofore possible.

•

Corrosion of Metals by Liquid Fertilizer Solutions by D. C. Vreeland and S. H. Kalin, United States Steel Corp., Monroeville, Pa.

Laboratory corrosion tests have been conducted on carbon steel, low-alloy steels, chromium and chromium-nickel stainless steels and aluminum to evaluate their suitability as constructional materials for storage, transport, and applicator tanks for "nitrogen" and "complete-mix" liquid fertilizers. Two types of corrosion tests were conducted; partial immersion of small specimens of each material in each fertilizer solution and simulated service tests in which small tanks fabricated of each of the test materials were partially filled with each of the fertilizer solutions. The amount and type of corrosion was evaluated by weight-loss determinations, thickness changes, pit-depth measurements, analyses of the solutions and metallographic examinations.

Results of the corrosion tests showed that in the nitrogen fertilizer solutions several chromium and chromium-nickel stainless steels and aluminum were not attacked while a plain carbon and a low-alloy steel were attacked. In the complete-mix fertilizer solutions, only the chromium-nickel stainless steels were not attacked while aluminum, several low-alloy steels, a plain carbon steel and three chromium stainless steels were attacked.

Service tests are being conducted on carbon steel and some of the steels that had satisfactory corrosion resistance in the laboratory tests.

Practical Plastics–

(Continued From Page 98)

users may evaluate this material for their specific requirements.

•

Design and Engineering of Plastic Materials of Construction by R. P. Whittier and O. H. Fenner, Monsanto Chemical Co., St. Louis, Missouri.

Proper selection of plastics as materials of construction in the chemical and allied industries can result in tremendous savings in maintenance costs. Recommended procedure is to choose the plastic most resistant to the environment and then to apply engineering design to circumvent any inherent, unfavorable properties of the specific plastic. Applications of this technique are discussed and illustrated, with particular reference to the use of polyvinyl chloride, polystyrene, polyethylene, polyester glass fiber reinforced and phenolformaldehyde resins in the fabrication of chemical processing equipment and use as structural materials.

Good engineering design in the application of plastics is dependent largely upon the availability of past perform-

(Continued on Page 109)

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Practical Plastics—

(Continued From Page 108)

ance data. Activities of Task Group T-5D-7, Engineering Design of Plastic Materials of Construction, are reviewed with reference to the accumulation and interpretation of such data dealing with short and long range exposure properties, dimensional stability, impact strength, aging and weathering characteristics, temperature limitations, as well as practical safety factors.

Significant High—

(Continued From Page 100)

to one or both of which differences its increased protectiveness must be ascribed. Instead of Fe_2O_3, A′ scale may contain a solid solution of 5 to 60 mole percent of Cr_2O_3 in Fe_2O_3. The relative amount of this phase exhibits a direct correlation and its Cr_2O_3 content an inverse correlation, with attack rate. The second difference is that as the temperature of oxidation or the Ni level of the alloy is increased, the $MnCr_2O_4$ phase is replaced by increasing amounts of an Fe-Cr-Ni spinel. For an 80Ni-20Cr alloy Ni0 is also present in A′ scale.

The less protective B′ scale resembles B scale in that no Cr_2O_3 phase is present. As in the case of A′ scale, no Fe_2O_3 is found but instead low chrome ferric-chromic oxide solutions occur the Cr_2O_3 content of which increases toward the inside of the scale. The most striking difference between B′ and B scale is the total absence of FeO from the former, even when the attack rate is extremely high.

These results are compared with existing scale data and interpreted using a tentative constitution diagram and a theory of Wagner.

•

Role of Minor Elements in the Oxidation of Heater Alloys of the Nickel-Chromium Series by Earl A. Gulbransen, Westinghouse Research Laboratories, Churchill Borough, Penna.

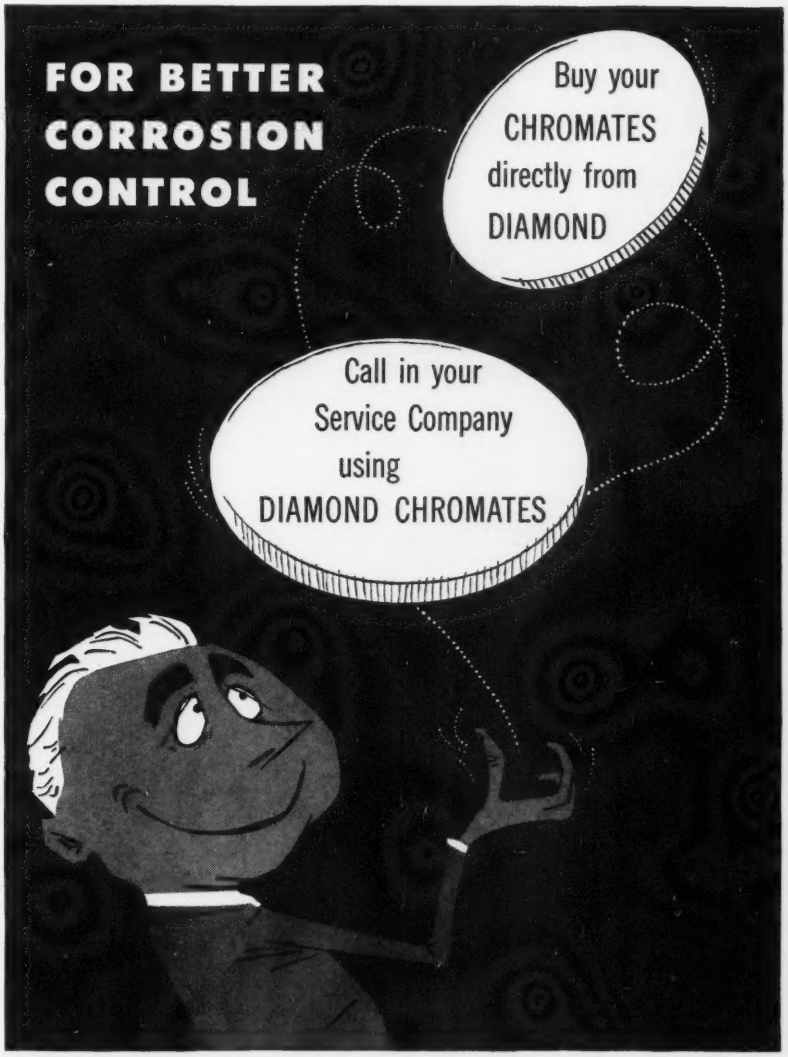
The various alloying elements are considered in terms of their effects on the physical and chemical structure of the oxide, oxide-metal interface and metal. Eight types of effects are discussed and where experimental data are available these data are used to illustrate the nature of the effect.

The eight types of effects are: 1) formation of new oxide of minor alloying element in outer layer, 2) formation of mixed oxide or spinels, 3) formation of oxide of alloying element in inner layer, 4) change in conductivity and the number of cation vacancies of the oxide film, 5) change in the physical properties and adhesive properties of oxide and oxide-alloy interface, 6) formation of inclusions and other types of defects in the metal, 7) concentration of impurities at the grain boundaries of the metal and 8) reaction of the alloying element with the surface oxide to give a volatile reaction product.

The critical role of certain elements such as calcium, cerium and silicon is attributed to the fact that these elements do not substitute easily in the spinel oxide structure and thus concentrate in certain sections of the oxide film.

•

A 10-Year Index to the material in Corrosion Technical Section 1945-54 inclusive will be published soon.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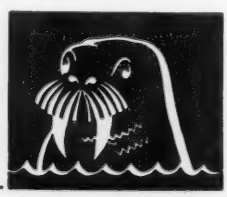

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CONFERENCE OFFICIALS—J. L. Waso, Dow Chemical Co., Midland, Mich., is co-chairman of the Chemical Inhibitor Symposium; J. F. Mason, Jr., The International Nickel Co., Inc., New York, is co-chairman of the Refinery Industry Symposium; W. F. Oxford, Jr., Sun Oil Co., Beaumont, and J. L. Battle, Humble Oil and Ref. Co., Houston, are co-chairmen of

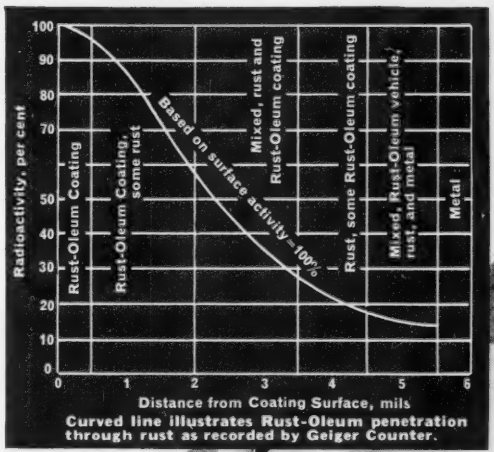
(Continued on Page 112)

RUST-OLEUM®

PENETRATION

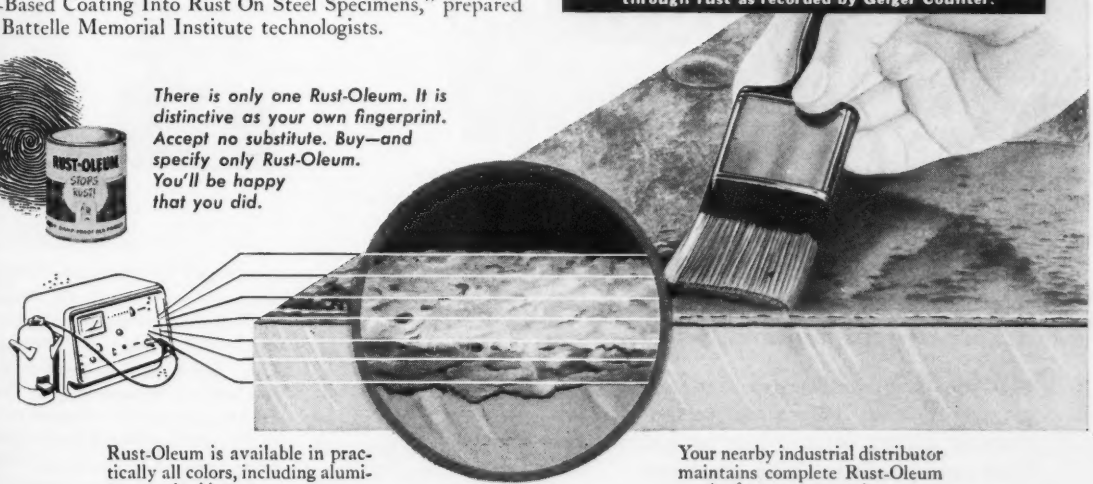
through rust to bare metal traced by Geiger Counter. To effectively stop rust—the vehicle of a protective coating, when applied over a sound, rusted surface—must penetrate through the rust down to bare metal. **Rust-Oleum does exactly that!—as proved by radioactive research!** Rust-Oleum's specially-processed fish oil vehicle was radio-activated and formulated into Rust-Oleum 769 Damp-Proof Red Primer—then applied to rusted test panels. Penetration *through rust* to bare metal by Rust-Oleum's specially-processed fish oil vehicle was then traced by Geiger Counter.

You stop rust, because Rust-Oleum's fish oil vehicle soaks deep down to bare metal and into the tiny pits where it drives out air and moisture that cause rust. You save, because this same *penetration* enables you to apply Rust-Oleum directly over rusted surfaces—usually eliminating costly surface preparations. Attach coupon to your letterhead for your thirty-page report entitled, "The Development of a Method To Determine The Degree of Penetration of a Rust-Oleum Fish-Oil-Based Coating Into Rust On Steel Specimens," prepared by Battelle Memorial Institute technologists.



Curved line illustrates Rust-Oleum penetration through rust as recorded by Geiger Counter.

There is only one Rust-Oleum. It is distinctive as your own fingerprint. Accept no substitute. Buy—and specify only Rust-Oleum. You'll be happy that you did.



Rust-Oleum is available in practically all colors, including aluminum and white.

Your nearby industrial distributor maintains complete Rust-Oleum stocks for your convenience.

RUST-OLEUM®

STOPS RUST!

See our Catalog in Sweets, or write for complete information.

ATTACH TO YOUR LETTERHEAD—MAIL TODAY

Rust-Oleum Corporation
2934 Oakton Street
Evanston, Illinois

- ☐ Complete literature including color charts.
- ☐ Thirty-page report on Rust-Oleum penetration.
- ☐ Nearest source of supply.

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1700 Caniff, Dept. K-2. Detroit 11, Michigan

How can we stop corrosion?

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Firm_____
Address_____
City_____ Zone____ State____

"We Stopped Corrosion at our Plant!"

"Corrosion was *rampant* inside and out before Truscon diagnosed our troubles and prescribed TRUSCON CHEMFAST, corrosion and chemical resistant coating with Devran (epoxy resin)."

● If you have *any* corrosion at your plant, stop it *now* before replacement costs eat gaping holes in your profits! Send coupon above—take advantage of Truscon experience and know-how.

Chemfast is a heavy-duty coating for protecting indoor and outdoor surfaces of wood, metal and masonry against moisture, acids and alkalis. It owes its toughness to Devran (epoxy resin).

IT'S ALIVE—IT'S DEVRAN!

TRUSCON Laboratories
Division of Devoe & Raynolds Co., Inc.

Sinclair

Sheppard

Vandelinder

Wade

Wasco

Woody

(Continued From Page 110)

the Oil and Gas Production Symposium; A. H. Roebuck, Continental Oil Co., Ponca City, Okla. is co-chairman of the High Purity Water Symposium; B. J. Philibert, Olin-Mathieson Chemical Corp., Baltimore, is co-chairman of the Chemical Industry Symposium; L. G. Sharpe, Napko Paint and Varnish Co., Houston, is co-chairman of the Pipe Line General Symposium; T. J. Maitland, American Telephone and Telegraph Co., and W. A. Sinclair, Detroit Edison Co., are co-chairmen of the Power and Communications Symposium; C. R. Johnson, Port of New York Authority, is co-chairman of the Cathodic Protection Symposium; C. C. Harvey, Ethyl Corp., Baton Rouge, and W. D. Manly, Oak Ridge National Laboratory, are co-chairmen of the Elevated Temperature Symposium; W. P. Cathcart and L. S. Vandelinder, Carbide and Carbon Chemicals Corp., South Charleston, W. Va., are co-chairmen of the Protective Coatings Symposium; L. R. Sheppard, Shell Pipe Line Corp., and C. L. Woody, United Gas Corp., Houston, are co-chairmen of the Pipe Line Group Discussions and L. B. Nelson, Shell Pipe Line Corp., and O. W. Wade, Transcontinental Gas Pipe Line Corp., Houston, are chairmen of the Pipe Line and Underground Round Table.

Papers on Electrodeposited Coatings Scheduled

Ordinances Fighting Smog Being Adoped Generally

Hackettstown Council (Easton, Pa.) adopted October 10 an amendment to its zoning ordinance to combat air pollution from industries moving to the town in the future. The amendment also bans certain types of industries from the industrial zone and limits industries to the use of oil, anthracite coal, gas or electricity.

The Albuquerque City Commission adopted an ordinance declaring that all substantial amounts of air pollutants are a nuisance.

Three environmental sanitation engineers will be hired by Massachusetts to conduct the state's air pollution program.

Ninety-two percent of the more than 2900 court cases involving violations of air pollution regulations resulted in conviction of the accused and levying of $132,278 in fines in Los Angeles.

ASME Division Sponsors Welding Show Sessions

The American Society of Mechanical Engineers' Metals Engineering Division will sponsor four sessions at the May 7-11 National Spring Meeting of the American Welding Society at Buffalo. Papers on welding nuclear reactor components also will be given among the 21 technical sessions planned.

ASME topics will be: Welding of Type 347 Stainless Steel, Joining of Dissimilar Metals, Material and Design Concepts Leading to Higher Welding Stresses in Pressure Vessels and What do Tests of Welds Tell Us?

Three papers on welding nuclear reactor components are planned as are sessions on gas-shielded arc welding and cutting, welding stainless steels, high nickel alloys, high strength aluminum, pressure vessels, pipe and tubing. Performance of welded joints between aluminum and stainless steels also will be covered.

Aluminum Use Contest

A contest offering prizes ranging from $10,000 to $500 for new designs and construction ideas for aluminum curtain wall buildings is being sponsored by Aluminum Company of America and the National Association of Architectural Metal Manufacturers. The program for the contest may be obtained from Paul Schell, AIA, c/o National Association of Architectural Metal Manufacturers, 228 North LaSalle St., Chicago 1, Ill.

•

By far the greater part of all technical material published in Corrosion is found in no other periodical. Two of every three editorial pages contain material with reference value.

Diesel Engine Operates on Coal Dust-Gasoline Mixture

A mixture of gasoline and coal dust is used as fuel in a Diesel engine by R. E. Harvey, Roanoke, Va. In operation, the volume of gasoline is reduced as the volume of coal dust is increased. Gasoline cannot be cut off completely because its function seems to be when burned to provide the ignition temperature at which the coal will be consumed.

Tests show the engine develops more power on coal than on gasoline and that cylinders are cleaner than they had been at any time since the engine was new. The experimenter hopes to get performance data on the engine to see what efficiencies are developed.

Rudolph Diesel's original intention in developing a prime mover competitive to the Otto cycle type was to make an engine that would burn coal. He abandoned his efforts and instead turned to the use of heavy oil.

(Editor's Note: This information was taken from Mineral Industries Journal, a quarterly publication of Virginia Polytechnic Institute, Blacksburg, Va.)

Corrosion Progress Viewed By Time-Lapse Photographs

Time-lapse motion pictures can be taken of the corrosion of a metal sample exposed to high temperature water. The device that makes this possible was developed by Daniel R. Grieser and Eugene M. Simons, Battelle Institute, Columbus, Ohio and was described at the Engineers' Joint Council Nuclear Science and Engineering Congress in Cleveland.

The device is an autoclave fitted with windows for admitting light and taking photographs. The procedure is important because it permits researchers to learn what would happen if a pinhole would develop in the cladding of a reactor fuel element.

Scholarship Is Offered

A scholarship aimed at interesting college students in the field of high temperature electric furnace operations is being offered by The Electrochemical Society. It will be called the F. M. Beckett Memorial Award, honoring the pioneering achievements of Frederick M. Beckett in the field of metallurgy.

Second or third year students working toward a BS will have the opportunity to qualify by completing a special project.

Instrument Society Meeting

The Instrument Society of America will hold its 11th Annual Instrument-Automation Conference and Exhibit in New York Coliseum September 17-21.

B-8 Committee of ASTM Will Sponsor Session at Boston

Eight papers on electrodeposited coatings and problems associated with them will be presented February 29 at Hotel Statler, Buffalo, N. Y. The symposium, sponsored by Committee B-8 on Electrodeposited coatings of the American Society for Testing Materials, will be given in two sessions. Membership in ASTM is not a prerequisite for attendance nor is a registration fee involved.

The program schedule is:

Morning Session: 9:30 am

Introductory remarks by the chairman.

History of ASTM Committee B-8, William Blum, Retired (formerly Director of Chemistry Section, National Bureau of Standards).

Corrosion Behavior and Protective Value of Decorative Copper-Nickel-Chromium and Nickel-Chromium Coatings on Steel, C. H. Sample, International Nickel Company.

Evaluation of Methods Available for Measurement of Surface Luster in Plated Coatings, Glade Bowman, Standard Steel Spring Division, Rockwell Spring and Axle Company.

Metal Cleaning Prior to Electroplating, S. Spring, Pennsalt Manufacturing Company.

Afteronon Session: 2:00 pm

Comparison of the Corrosion Behavior and Protective Value of Electrodeposited Zinc and Cadmium Coatings on Steel, C. H. Sample and R. B. Teel, International Nickel Company; and A. Mendizza, Bell Telephone Laboratories.

Evaluation of Supplementary Conversion Coatings on Zinc and Cadmium, R. E. Harr, Western Electric Company.

Atmospheric Exposure of Electroplated Lead Coatings on Steel, A. H. DuRose, Harshaw Chemical Company.

The Standard Salt Spray Test—Is It a Valid Acceptance Test, A. Mendizza, Bell Telephone Laboratories.

Armour Program Covers Welding of Stainless

Welding Austenitic Stainless Steel for High Temperature Service by Roy W. Emerson, Pittsburgh Piping and Equipment Co.; Joining of Heat Resistant Alloys by Harold E. Schultz, General Electric Co. and Welding Problems in Nuclear Reactors by Robert A. Noland, Argonne National Laboratory are three of the papers to be presented at Chicago February 1-2. The sessions, at Armour Research Foundation of Illionis Institute of Technology is sponsored jointly by the institute and Chicago Section of the American Welding Society.

Smog Study Funds Sought

Funds from the $5 million appropriation voted the United States Attorney General by Congress for a study of air pollution will be sought by the Chicago Air Pollution Committee.

POSITIONS WANTED and AVAILABLE

- **Active and Junior NACE members and Companies seeking employees may run without charge two consecutive advertisements annually under this heading, not over 35 words set in 8 point text type.**
- **Advertisements to other specifications will be charged for at $10 a column inch.**

Positions Wanted

Manufacturer's Representative, corrosion engineer with established customers in chemical and related industries of Michigan seeking additional line. Reply to CORROSION, Box 56-2.

Corrosion Engineer—Experience includes formulation, application and evaluation of protective coatings; cathodic protection systems; instrumentation; materials; methods. 15 years experience. BChE, MChE, Registered Engineer 2 states. Desires position in research, applications engineering, or development. CORROSION, Box 56-3.

Responsible position wanted with proven frontrunner company. Age 35 with industrial sales, engineering, and supervisory experience. NACE member. Southeast location desired. CORROSION, Box 56-4.

Positions Available

Technical Sales and Service Engineer to represent Manufacturer of Plastic Materials of Construction in Linings in Corrosion Resistance Service. Excellent opportunity with several territories available. Write full background to CORROSION, Box 56-5.

BOOK REVIEWS

Official Yearbook, Federation of European Technical Associations of the Paint and Associated Industries. (In French, English and German). 157 pages, 5⅜ x 8½, paper. 1955. Availability not indicated.

A list of the names and addresses of members associated with this organization from Belgium, France, Holland, Italy, Switzerland, Germany and Spain. Purpose, function and activities of the cooperating organizations are explained.

•

Corrosion in Action. 48 pages, 8½ x 11, cloth. 1955. The International Nickel Co., Inc., 67 Wall Street, New York 5, N. Y. Not available.

The narrative accompanying the Inco motion picture "Corrosion in Action" with selected illustrations from the picture in full color. An exceptionally lucid exposition of corrosion fundamentals. Issued in limited edition. Copies are not available.

•

Kathodische Bescherming van Ondergrondse Buisleidingen. (Cathodic Protection of Underground Structures) In Dutch. A Report of Corrosion Commission II for the Study of Underground Corrosion of Pipe. Publication 35 of the Metaalinstituut T.N.O. Afdeling Corrosie. By J. F. Bogtstra, Metaalinstituut T.N.O., Afdeling Corrosie, Delft and M. Audeman, Koninklijke/Shell Laboratorium, Amsterdam. July, 1955. 41 pages, 8¼ x 11¾, paper. Per copy, 5 francs.

This appears to be designed in the manner of a handbook of procedures in cathodic protection of underground structures. Considered are electrochemical testing, covering potentials, galvanics, concentration cells, aeration, stray currents, polarity. Investigation of the source of corrosion covers soil agressiveness, resistance, pipe potential measurements. Installation data include external current sources, galvanic anodes, isolation, locating ground beds and testing.

•

The Metallurgy of Zirconium. 776 pages, 6 x 9, cloth. July 29, 1955. Editors: Benjamin Lustman and Frank H. Kerze, Jr. McGraw-Hill Book Company, Inc., 330 West 42nd St., New York 36, N. Y. Per copy, $10.

A technical discussion by more than 50 contributors on the occurrence, reduction, refining, properties and uses of zirconium and its alloys. Emphasis is on the application of zirconium to nuclear reactors, with a liberal discussion of its applicability to other uses in the chemical, metal and electrical industries. Use in commercial installations is fully covered.

Corrosion of zirconium and its alloys is discussed in a 120-page chapter. This considers, among many other things, interstitial structures, crystallography and composition of phases formed, thermodynamic relations in gas reactions, corrosion in water and steam, acids, bases and salts; effect of zirconium purity on corrosion resistance, corrosion resistance of zirconium alloys, corrosion in liquid metals and electrode reactions.

The book is liberally illustrated with diagrams and microphotographs and has many tables of data. Each chapter concludes with references to material discussed.

Spectrographers to Meet

The American Association of Spectrographers is planning its seventh Annual Conference in Chicago May 4. Subject of the conference will be New Developments and Techniques in Spectroscopy.

Contributed papers are solicited. Abstracts should be sent before March 16 to John P. Merutka, chairman; H. M. Harper Company, 8200 Lehigh Ave., Morton Grove, Ill.

Steel Founders' Meetings

Meetings of the Steel Founders' Society of America have been scheduled as follows:

Annual meeting, Drake Hotel, Chicago, March 19-20.

Fall meeting, Greenbriar, White Sulphur Springs, W. Virginia, September 24-25.

Technical and operating conference, Carter Hotel, Cleveland, November 7-9.

Alaskan Pipeline Completed

A 630-mile 8-inch products pipe line has been completed between the ice-free port of Haines, Yukon Territory to Fairbanks, Alaska. Welded joints on the line were examined visually and about 20 percent were checked with gamma cameras. The final hydraulic test showed no leaks in any field weld.

Nuclear Standards Sought

The American Standards Association has been asked to help develop standards for use in connection with nuclear reactors leading to the safest and most profitable use of nuclear energy in industrial processes.

Aviation Division to Meet

The 1956 Aviation Division Conference of the American Society of Mechanical Engineers will be held March 14-16 at Los Angeles. Sessions are to be held jointly with the American Rocket Society.

EQUIPMENT INSPECTORS

(Ages 25-32)

Career employment opportunities with a major integrated U. S. oil company operating in South America. Vacancies exist in refinery equipment inspection positions at levels requiring two to four years of refinery equipment inspection experience. Candidates must be graduate engineers, preferably mechanical or metallurgical. Salary, including bonus, $11,000-$12,500, depending on qualifications and experience. Liberal employee benefits and home vacations with travel expenses. Send complete resume of education, personal data and work experience. Interviews will be arranged for qualified candidates. All replies confidential. Box 1221, Dept. Q-27, New York 1, N. Y.

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- Built of nonconductive polyester resin with a fiber glass filler.
- Compressive strength of 18,000 psi.
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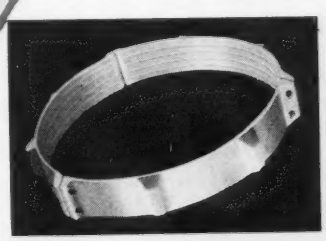

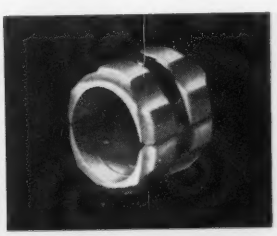

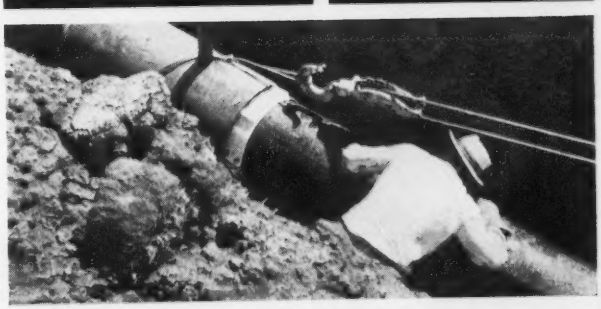

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Equipment Services NEW PRODUCTS Materials Literature

Mylar polyester film is described technically in an 8-page folder MB-4 obtainable from DuPont Film Department, Wilmington 98, Delaware.

•

Precision Instruments for Industry are described in a bulletin issued by Illinois Testing Laboratories, Inc., 420 North LaSalle St., Chicago 10, Ill.

•

Reactions of Carbon With Carbon Dioxide and with Steam, Institute of Gas Technology Research Bulletin 19 by C. G. von Fredersdorff describes high temperature (1700-2500 F) reactions between a solid fuel and oxidizing gases.

•

Dow Silicone Products are covered fully in the 1956 reference guide which describes almost 150 of the most generally used silicone products. The publication was issued by Dow Corning Corp., Midland, Mich.

•

Anti-Corrosive Metal Products Co., Inc., Castleton-on-Hudson, N. Y. has issued a catalog of stainless steel fastenings. The catalog covers 9000 items and sizes in different stainless analyses.

CORROSION
is a luxury
you can't afford!
Protect your investments with
Harco Cathodic Protection Systems
Every ferrous metal structure you own (underground pipe lines, oil and water storage tanks, water works equipment, etc.) is being stolen from your profits.
Harco's job is to protect you. Cathodic protection systems by Harco will STOP corrosion in its tracks. What's more, Harco job-engineered-systems provide the necessary testing, drawings, materials and installation.
A Harco Cathodic Protection System will pay for itself many times over. It costs nothing to investigate the tremendous savings available to you.
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CATHODIC PROTECTION DIVISION
Cleveland • New York • Chicago • Philadelphia • Detroit • St. Louis • Louisville • Minneapolis • Oklahoma City
Los Angeles • Seattle • Houston • Atlanta • Lynchburg • Pittsburgh • Albany • Davenport • Toronto, Canada

Turbidity, dissymmetry and depolarization of dilute solutions of high molecular weight compounds can be determined with the new Brice-Phoenix Universal 1000 Series Light scattering Photometer. Complete information can be obtained from Phoenix Instrument Co., 3803-5 North Fifth St., Philadelphia 40, Pa.

•

Red Lead Alkyd Vehicle Primer for Industrial and Marine Environments is described in Red Lead Technical Letter No. 10, available from Lead Industries Association, 420 Lexington Ave., New York 17, N. Y.

•

Stainless Fasteners of Allmetal Screw Products, Co., Inc., Garden City, N. Y. are covered in the company's stock list and data book. The 52-page book is thumb-indexed. Engineering data relating to composition, properties, applications and weights of stainless steels are included. Copies are available.

•

Metal Surface Treatments Manual, a thumb-indexed, loose-leaf booklet includes among other things a "Surface Treatment Selector Chart" which tabulates relative to service status the recommended repair specification numbers listed in the book. For example, when service includes abrasion-corrosion-heat and there are abrasive particles in hot corrosive media, a number of surface preparations are listed including electrodeposition of hard chrome plate, welding deposit on surface and ceramic coating. Copies are available from Texas Alloy Products Co., 1403 North Post Oak Road, Houston.

•

X-Ray Emission lines of the elements, arranged in the order of their wavelengths, are tabulated in the Norelco Reporter, November-December, 1955 issue. The periodical is issued bimonthly by North American Phillips Co., Inc., 750 South Fulton Ave., Mount Vernon, N. Y.

•

Kel-F materials, products of M. W. Kellogg Co., P. O. Box 469, Jersey City 3, N. J. are described in several publications available on request from the company. Technical Bulletin 1-1-55 P.1 gives the physical, electrical, chemical and mechanical properties of the material. A Buyers Guide lists the names and addresses of companies who are converters and processors and those who manufacture items from the material. Companies are cross-indexed by the type of item they make. Application Techniques for Kel-F Dispersions are described in an 18-page booklet of that title. The correct ways to apply the dispersions to metallic and non-metallic surfaces by spraying, spread coating, dip and flow coating and baking are given.

•

Design of Magnetostriction Transducers, 38-page and cover booklet published by The International Nickel Co., Inc., 67 Wall Street, New York 5, N. Y. is available from the company's Reader Service Section. Design of the transducers

(Continued on Page 117)

NEW PRODUCTS

(Continued From Page 116)

which convert electrical energy into mechanical output energy is described. Vibrations produced by the device can be used for numerous applications involving high-cyclic vibrations.

•

Polypenco Non-Metallics, Nylon, Teflon, Q-200.5, K-51 and described in a brochure issued by the Polymer Corp. of Pennsylvania, Reading, Pa. Specific uses are described.

•

MSA Air Line Respirators, designed for use in atmospheres including gases from welding and cutting operations, toxic dusts, paint spray vapors and fumes from molten metals are illustrated and described in a 4-page bulletin available from Mine Safety Appliances Company, 201 N. Braddock Ave., Pittsburgh 8, Pa.

•

Environmental Stress cracking of polyethylene films in contact with release agents has been explored by the Bakelite Company and reported in its Technical Release No. 5, December 1955.

•

Steelcote Manufacturing Co., 3418 Gratiot St., St. Louis, Mo. has issued its catalog No. 56 which describes the characteristics of a wide variety of coatings. The company's products include numerous paints formulated with oil base, alkyd, phenolic, silicone, vinyl, bitumen, acrylic and other solids and vehicles.

•

Fortisan-36, a new high performance polymer is now being produced at the Rome, Georgia plant of Celanese Corporation of America. The material, said to have wide use in numerous applications, including high pressure hose, plastic laminates and oil hose is based on the cellulose molecule. It will be available initially in 800 and 1600 denier continuous filament.

•

Kaiser Aluminum and Chemical Corporation has initiated an expansion program designed to increase its primary aluminum capacity to 654,000 tons annually. New plants in West Virginia and Louisiana are contemplated.

•

Molding Phenolics, a 20-minute, 16-millimeter sound film produced by Bakelite Company describes phenolic molding processes. Prints may be borrowed, with an instructor's manual, from Bakelite Company, Technical Film Library, 292 Madison Ave., 10th Floor, New York 17, N. Y. There is no rental charge.

•

Sintered Metal Filters, designed for use at high temperatures and at differential pressures up to 500 psi are said by the manufacturers, Purolator Products, Inc., Rahway, N. J. to handle particles as small as one micron in size. Made in stainless steel, Monel or other metals, the filters can be used in corrosive media.

•

Amercoat Protective coatings systems are described in two 4-page folders Am 3i and 3j, by Amercoat Corp., 4809 Firestone Blvd., South Gate, Cal. Characteristics of the company's coatings systems are described and the engineering services of the company detailed.

B & W Heat Exchanger and Condenser Tubes, seamless and welded are described in Bulletin TB-329B by Babcock & Wilcox Co., Beaver Falls, Pa. Data on carbon, low chromium, intermediate chromium, nickel and stainless steels are given.

•

Conoflow Corporation, Philadelphia, manufacturer of pneumatic valve control equipment has been purchased by the Walworth Company, New York, N. Y.

•

Starfire, a ceramic-on-steel wall tile, guaranteed against crazing, cracking or color fading by manufacturers, The Bettinger Corp., Waltham, Mass. has been developed for use in the mass home building field. Tile are applied directly on dry wall surfaces with a waterproof and mildewproof material.

Brilok Nylon Stop Nut, a one-piece, washer-faced, resilient hexagon nut simultaneously self-tapping, locking and insulating is manufactured by The American Screw Company, Willimantic, Conn. It is available currently in sizes number 4, 6, 8, 10 and ¼-inch.

•

Platecoil heat transfer units manufactured by Tranter Manufacturing Co., Inc., Lansing, Mich. can be used now up to 150 psi compared to previous maximum of 100 psi.

•

Aluminum Rubbertex, a caulking compound combining rolled aluminum flakes and rubber is used for outside caulking of aluminum components. High flexibility is claimed.

(Continued on Page 118)

WHEN IT COMES TO SERVICE COME TO REILLY

Dick Renshaw is well known to all Reilly Enamel users because he heads up Reilly's Hot Enamel Field Service Group.

He is a practical Corrosion Engineer and has an intimate knowledge of the composition of enamel and of the techniques of its manufacture and use. As a result, his capabilities are held in high esteem throughout the industry.

Reilly COAL TAR PRODUCTS

Reilly Tar & Chemical Corporation

MERCHANTS BANK BUILDING, INDIANAPOLIS 4, INDIANA

Sales Offices in Principal Cities

NEW PRODUCTS

(Continued From Page 117)

Monel Toilet Flush control units made by Micek Mfg. Co., Walsenburg, Col. are corrosion-free. The units are sold by Mountain View Sales Co., Inc., Box 1009, Canon City, Col.

•

Centri-F Pump, a portable electric pump, is designed for pumping acids from open as well as closed vessels. It is manufactured by General Scientific Equipment Company, P. O. Box 6798, Philadelphia 32, Pa.

Gaco Roof, a liquid Neoprene roof coating material can be applied with standard long-handled roofer's brush and air-cures in one hour into an elastic coating that will not crack, chip or peel and is fire resistant. Manufacturers, Gates Engineering Company, Wilmington, Del. say the material is not affected by rain, sun, ice, salt spray or corrosive fumes and may be applied to asphalt, asbestos, slate or metal roofs. No preparation beyond sweeping and driving protruding nail heads is required.

•

Army Package Power Reactor, developed by Alco Products, Inc., Schenectady 5, N. Y. will produce power at a cost of about 16.8 mills per kwh, according to Kenneth Kasschau, manager of Alco's atomic engineering section.

•

Ultrasonic power transducers and improved generators operating at 40 kc/sec are available from Branson Ultrasonic Co., Division of Branson Instruments, Inc., 194 Richmond Hill Ave., Stamford, Conn. The transducers are particularly suitable for metal cleaning operations.

•

Hagan Corporation has designed a multitube centrifugal dust separator which in some installations carries a minimum guarantee of 93 percent and in actual tests has efficiencies as high as 97 percent. These results far exceed requirements of the Allegheny County, Pennsylvania smoke control ordinance.

•

Test Kits sufficient to permit diffusion of chromium into small pieces of ordinary steel are available from Alloy Surfaces Co., 1115 N. 38th St., Philadelphia 4, Pa. The kits permit firms with the furance equipment to test the diffusion process offered by the company.

•

Magnetic Particle Inspection without the use of electric power is possible with a new inspection kit developed by Magnaflux Corp., 7300 West Lawrence Ave. Chicago 31, Ill. Magnets supplied with the kit permit use of wet and dry power methods on equipment in hazardous or out-of-the-way areas.

•

Glid-Iron, a 100 percent solids resin coating, has excellent adhesison to wood, metal and concrete and is resistant to chemicals and oils. Interior applications to silos have been found to protect concrete from the effects of silage. Temperature range is —20 to 212 F. Manufacturer is The Glidden Company, Cleveland, Ohio.

•

Allflex, a hose suitable for use with air, oil, water and mild chemicals is available from Manhattan Rubber Division, Raybestos-Manhattan, Inc., Passaic, N. J.

•

Tantalum can be tested for resistance to corrosives by users with kits available from Fansteel Metallurgical Corp., North Chicago, Ill. Coupons in the kit can be exposed to corrodents to determine their resistance.

•

Water-Skipper, a proprietary aerosolized water repellent which can be used in many applications to prevent corrosion is available from Textile Adjuncts Corp., 876 Pacific St., Brooklyn 38, N. Y.

•

DXM-103, a polyethylene resin which is more dense than standard resins, with improved tensile strength, increased surface hardness, improved resistance to staining and slightly reduced permeability has been developed by Bakelite Company, a Division of Union Carbide & Carbon Corp.

•

Corrosion-Resistant anti-flash screens in the nozzles of stainless steel faucets introduced by Economy Faucet Co., 12 New York Ave., Newark 1, N. J., make them useful with volatile and flammable liquids. The faucets are made of Type 304 stainless and the screen of Kel-F. All frictional contact in the device is limited to Kel-F rings moving against the inside wall of the body chamber.

MEN in the NEWS

George T. Paul, formerly a member of Princeton University's faculty, has joined International Nickel Co., Inc., as a member of the Development and Research Division's Corrosion Engineering Section in New York. Among his first undertakings will be preparation of a book on the corrosion of stainless steels. He holds a PhD in chemical engineering, and MA in chemistry from Columbia University. Before joining Inco he was a chemical engineer in the Process Engineering Section of the American Cyanamid Company's Organic Chemical Division at Bound Brook, N. J.

•

Russell W. Mumford, vice-president and consulting engineer for American Potash and Chemical Corp. retired recently after 35 years' service.

Charles M. Hammond has been granted a research fellowship at University of Michigan established by The International Nickel Co., Inc. His fellowship work concerns the effect of alloying elements on microstructure and stress rupture properties of nickel base alloys.

•

Wingate A. Lambertson, formerly assistant director and professor of silicate chemistry of the Institute of Silicate Research at University of Toledo has been appointed assistant to the manager, Research Branch of the Research and Development Division of the Carborundum Company.

•

Frank J. Kiernan has been appointed technical engineer of protective coatings sales for Barrett Division, Allied Chemical and Dye Corp. He formerly was assistant chief engineer of the United States Stoneware Co.

Edward J. Vargo has been named chief metallurgist and **C. B. Beener,** chief engineer of Alloy Precision Castings Co., Cleveland.

•

H. E. Hudson, Jr., formerly chief engineer of the Illinois State Water Survey is now associated with the New York engineering firm of Hazen and Sawyers. His experience includes research work on removal of chemical agents from water for University of Illinois, work with Army Engineers investigating German military water purification methods in Europe and as filtration engineer for South District Plant, Chicago.

•

Ernest V. Gent, for 20 years secretary and executive vice-president for American Zinc Institute retired December 31. **John L. Kimberly** has been appointed executive vice-president succeeding him.

(Continued on Page 120)

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MEN in the NEWS

(Continued From Page 119)

David W. Pettigrew has been named administrative assistant to the institute.

•

Edmund M. Wise has been made assistant to the vice-president-manager of the Development and Research Division of The International Nickel Co., Inc. He has been head of Inco's development and research activities in the fields of platinum metals and applied physics since 1933.

•

Gilbert R. Semans is now assistant director of metallurgy and research of Jessop Steel Co., Washington, Pa.

•

Paul Erlandson, former chairman of the physics department and assistant vice-president of Southwest Research Institute, San Antonio, Texas has been named director of the department of physics of Continental Can Company's new Central Research and Engineering Division. Among other things he will be concerned with the ionization radiation sterilization program of the company.

•

E. G. Holmberg, for nine years chief metallurgist of Alloy Steel Products Co., Linden, N. J. has joined the Corrosion Engineering Section of the International Nickel Company's Development and Research Division in New York. Before his employment by Alloy Steel Products Co. he was for 11 years metallurgist with E. I. du Pont de Nemours & Co. at its Belle Works in West Virginia.

•

J. E. Himmelrich has been assigned to the Tulsa office of Pittsburgh Coke & Chemical Company and M. P. Ellis has been moved to the company's Pittsburgh office.

•

Edward D. Youmans, vice-president in charge of research and products development of The Okonite Company died at his home December 18. He was 58 years of age.

•

Arthur L. Phillips has been appointed editor of the Welding Handbook by the American Welding Society. He is author of over 200 articles on welding and related subjects.

•

Allan E. Chester, vice-president of Promat Division, Poor and Company died November 22 en route to Honolulu. He was 54 years old. He was active in a number of technical organizations.

•

Josef F. Palme, Jr. has been named to the sales engineering staff of Bart Laboratories, Co., Inc., Belleville, N. J. He formerly was employed by Reichold Chemicals Inc. and Essex Rubber Company.

•

Bart Wright and **Roger Sullivan** have been appointed production superintendent and production engineer respectively of the Becco Chemical Division, Food Machinery and Chemical Corp. plant at Buffalo, N. Y. **Norman Michaelis** has been named supervisor of the control laboratory succeeding Mr. Wright and Mr. Sullivan's position in the engineering research laboratory will be filled by **John Parrone.**

CORROSION ABSTRACTS

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1. GENERAL

1.2 Importance

1.2.5

Legislation by Disaster. *Chem. Eng. News*, **33**, No. 10, 942-944 (1955) Mar. 7.

At the Berg Laboratories in Philadelphia last October a 4,000 gallon tank containing 2,145 gallons of four parts by weight of o-dichlorobenzene, two of propylene dichloride, and one of ethylene dichloride, exploded. Ten people died and thirty-seven were injured from the blast. The report of the disaster stated that the tank had been fabricated for a brewery, of material similar to Alcoa 2S aluminum. Various openings supplied for gauges had been welded shut and the tank vent was dirty and partially clogged. The report stated that the propylene dichloride and ethylene dichloride vaporized and condensed above the liquid level in holes left by the welding operation. Solar heat caused the propylene dichloride to react with aluminum to form aluminum chloride. The chloride then flowed out of the holes and returned to the mother liquor where it catalyzed the reaction between the mother liquor and aluminum causing a build-up of pressure and eventual explosion. New ordinances to curb chemical explosions have been recommended because of the disaster.—ALL. 9365

1.5 Directories of Material

1.5, 6.5

Metals Properties. S. L. Hoyt, Editor. Book, 1954, 433 pp. McGraw-Hill Book Co., New York and London.

This book, prepared under the aegis of the American Society of Mechanical Engineers, is the second published part of the four-volume *A.S.M.E. Handbook*: the volume on "Design" has already appeared. About two-thirds is devoted to steels, one-third (135 pp.) to non-ferrous metals and alloys (copper, aluminum, nickel, zinc, lead, tin, magnesium; and the so-called super-alloys). Information is set out in tabular form, including composition; form; technological, physical and mechanical properties. In some cases, information is given in considerable variety and detail, including, e. g., properties at various temperatures and directional properties. This volume should become a standard work of reference.—BNF. 9729

1.6 Books

1.6, 5.1, 4.6.12, 8.9.3, 8.4.3

Combating Corrosion—A Special Symposium. A Digest of the Proceedings of the Corrosion Control Short Course, Extension Study Center, North Campus, University of Oklahoma, Tulsa. April, 1955, 184 pp. Published by Business and Industrial Services, Extension Division, University of Oklahoma, Norman.

Consists of 26 papers given during the Corrosion Control Short Course, April 5-7, 1955, sponsored by the College of Engineering and Extension Division, the University of Oklahoma in cooperation with Central Oklahoma Section, National Association of Corrosion Engineers. Some of the papers are in brief abstract form only.

Titles and authors are as follows: Controlling Corrosion Thru NACE by John E. Loeffler; Theory of Inhibitors, A. H. Roebuck; Corrosion Inhibition and Bacteriological Control in Water Flooding, W. J. Ries; Application of Organic Inhibitors in Water Flooding, J. B. Robinson; Casing Corrosion in the Petroleum Industry, Jack L. Battle; Electrical Grounding in Cathodically Protected Systems, O. W. Everett; Corrosion Problems in Parallel and Crossing Systems, C. L. Mercer; Views of Management on Corrosion Control, Carl Cloud; Selling Corrosion Control to Management, J. C. Spalding, Jr.; Plastics for Pipe Coating, R. B. Bender; Sacrificial Anodes, P. F. George; Protecting Pipelines by Impressed Voltage, Scott Ewing; External Coatings for Pipelines, W. H. Stewart; Unwanted Currents on Pipelines, James R. Cowles; Prevention of Caustic Embrittlement in Boilers, James S. Connors; Corrosion Control in Steam and Condensate Systems, John J. Maguire; Corrosion Problems in Recirculating Cooling Tower Water Systems, R. S. Wise; Cathodic Protection in Refineries, V. W. Hatchett; "It's Up to You," T. L. Cannfield; Test Methods for Corrosion Mitigation, James R. Cowles; Microbiological Corrosion of Iron and Steel, D. M. Updegraff; Corrosion Problems in the Handling and Use of Sulfuric and Hydrochloric Acids, Harold E. Crook; Selection of the Proper Surface Coating for a Given Application, John W. Nee; Corrosion Resistance of Sprayed Metal Coatings, Walter B. Meyer; Use of Glass Coatings in Combating Corrosion, F. W. Nelson. 9451

1.7 Organized Studies of Corrosion

1.7.1

Work of the Centre d'Etudes de Chimie Metallurgique. (In French.) Pamphlet, 1954, 70 pp. Issued from the Centre d'Etudes de Chimie Metallurgique, 15 rue Georges-Urbain, Vitry-sur-Seine (Seine), France.

This establishment is a branch of the Centre National de la Recherche Scientifique. This pamphlet gives a detailed and well-illustrated account of investigations carried out in the last 10 years, including preparation of pure metals; application of radioactive tracer elements to metallurgical problems and to analysis of impurities in metals; corrosion and protection of metals; solid state reactions and non-stoichiometric compounds; metallographic study of uranium, titanium, zirconium, beryllium, etc.—BNF. 9713

1.7.1, 2.2.2, 2.2.7

Report on the Activities of Commission No. 4 for Protection Against Corrosion of ABEM. Part II. Technical Report. (In French.) March, 1955, 28 pp. Association Belge Pour L'Etude, L'Essai et L'Emploi des Materiaux, 38, Rue de Naples, Brussels, Belgium.

An illustrated report on the 1954 work done by the Belgian commission for pro-

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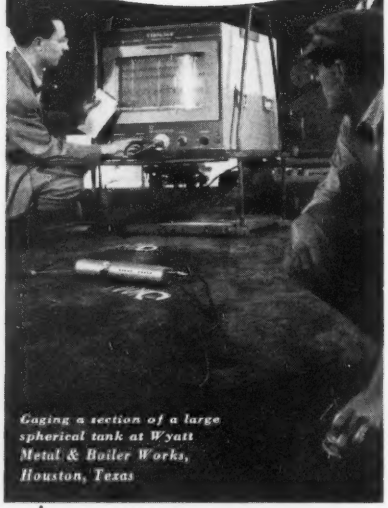

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tection against corrosion. Organization of and details concerning the progress of tests of materials in atmospheric, marine and laboratory environments are given. A program of new investigations is outlined and a list of publications issued during 1954 included. 9574

1.7.1, 3.8.4, 1.6

Proceedings, Meeting of Centre Belge D'Etude de la Corrosion. (In French.) April, 1955, 86 pp. Centre Belge D'Etude de la Corrosion, 21 Rue des Drapiers, Brussels, Belgium.

Proceedings of a meeting of Cebelcor held April 13-14, 1955. Reports are given on the progress of the studies being conducted by Cebelcor. Numerous diagrams of data are included illustrating the thermodynamics of the various problems under study.

A list of the publications issued so far by Cebelcor is appended. 9550

2. TESTING

2.2 On Location Tests

2.2.2

Report of Committee A-5 on Corrosion of Iron and Steel. Report of Subcommittee XVI on Field Tests of Atmospheric Corrosion of Hardware. A. MENDIZZA. Paper before Am. Soc. Testing Materials, 58th Ann. Mtg., Atlantic City, June 26-July 1, 1955. ASTM Preprint No. 4, 1955, 30.32.

Reports of inspections for 1953 and 1954 on hardware, structural shapes, and tubular goods exposed to the atmosphere on test racks at State College are tabulated. Other locations were not inspected this year. Little progress of corrosion was noticeable at State College. Pinhole rusting on some lead-coated samples was rated lower in 1954 than in 1953. This was due in some instances to higher rust rating.—INCO. 9586

2.2.2, 5.4.5

About the Studies of Exposure Tests with Painted Steel Panels. A Report of Corrosion Commission IVa. (In Dutch.) April, 1955, 36 pp. Mataalinstituut T.N.O. Afdeling Corrosie, Postbus 49, Delft, Holland.

This is the sixteenth report of this commission which started tests at five sites in 1935. Details of preparation of panels, coating systems, length of tests, nature of environment tnd other data are given. The information includes use of primers without finishing systems. These showed best results obtained with primers based on pigment mixtures containing at least 50 percent of red lead in raw linseed oil. Red iron oxide primers showed poor performance.

Tests with complete systems of primers and finishing coats involved various combinations of red lead primers, while lead finishing coats, asphaltic bitumen and water-resistanf varnish. Numerous illustrations and tabulated data. 9577

2.2.2, 7.7, 7.8

Report of Committee A-5 on Corrosion of Iron and Steel. Report of Subcommittee XV on Atmospheric Exposure Tests of Wire and Wire Products. (Covers 1953 and 1954 Inspections). F. M. REINHART. Paper before Am. Soc. Testing Materials, 58th Ann. Mtg., Atlantic City, June 26-July 1, 1955. ASTM Preprint No. 4, 5-29 (1955).

Report summarizes results of atmospheric corrosion tests on wire and wire products through 1954 and presents in detail the data from 1953 and 1954 inspections. Materials are mostly bare and zinc-coated steel wires and wire products, but copper-covered and lead-coated steel wires and chromium and chromium-nickel steel wires are also included. Specimens have been exposed for 18 years at 11 sites, including rural, marine and industrial locations. Extent of corrosion is measured by weight loss determination, by visual examination and by tension tests. Results are tabulated.—INCO. 9655

2.3 Laboratory Methods and Tests

2.3.6

Thickness Measurements of Thin Films by Multiple-Beam Interferometry. T. W. BARTLETT AND F. L. BALL. U. S. Atomic Energy Comm. Pubn., KLI-1425, 1952 (unclassified 1954), 12 pp. on microcards).

An evaluation has been made of multiple-beam interferometry to determine the applicability of these techniques to the measurement of thicknesses of corrosion films, vacuum-deposited metal coatings, etc. Two techniques are described for measuring the thickness of thin films; the more useful was one employing fringes of equal chromatic order. The standard deviation on measurements of films < 1000 A. was rarely > 50 A.; deviation such as this can be explained on the basis of the precision of wavelength measurement. Well-defined topographical features such as sharp ridges, facets, or discontinuities may be observed by Fizeau fringes. 8 references.—MA. 9705

2.3.7

Measurement of Plating Thickness. G. HOWELLS. *Corrosion Technology*, **1**, No. 7, 233-236 (1954) Sept.; *Marconi Instrumentation*, **4**, No. 5, 113-116 (1954) Mar.

Methods of measuring coating thicknesses by direct, chemical, magnetic and X-ray methods are discussed in detail. Measurements are usually affected to some extent by the quality (i.e. porosity, crystal structure, amount of alloying) of the coating and this must be taken into account when the final accuracy to be expected is considered. Graphs, diagrams and nine references.—INCO. 9719

2.3.7

Measuring Film Thickness. F. D. JOHNSON. *Can. Paint, Varnish Mag.*, 28, No. 12, 5-8, 43-45 (1954) Dec.

A survey is made of various methods of measuring thickness of wet or dry films, covering mechanical, magnetic, electric and radioactive methods.—RPI. 9728

2.3.7, 5.3.2

Two Methods of Studying the Porosity of Electrodeposited Coatings: Application to the Study of Chromium Electrodeposits. M. BONNEMAY. Chrome Dur, 1954, 5-9: Published by Centre d'Information du Chrome Dur, Grand Palais, Porte C, Paris 8, France.

Bonnemay describes two methods of estimating the porosity of chromium electrodeposits: 1.) Deposits of chromium on copper were immersed in cupric sulfate solution, and the time taken for the electrode to develop the Cu/Cu^{++} potential was related to the diffusion of the electrolyte through the deposit. 2.) Chromium was deposited on to radioactive copper, and the specimen immersed in non-active cupric sulfate solution. The

time which elapsed before the electrolyte became active was measured and found to be in good agreement with the time for establishment of the copper potential. Method 1.) was evaluated with respect to deposit thickness and electrolyte conditions, and used to estimate the porosity of various chromium deposits. The process is discussed theoretically. It is thought that, for thin deposits, at least, the rise in potential follows the penetration of the electrode by the electrolyte.—MA. 9799

2.3.7, 5.3.2

A Nonoxidizing Heat Test for Plating Adhesion. I. W. Marcovitch. *Plating*, **42**, No. 6, 749-750 (1955) June.

Determination of adhesion of electroplated coatings to base metal by nonoxidizing heat test is discussed. Parts are immersed in fat or oil heated between 475 and 500° F. for two minutes; quenched in kerosene; and degreased to remove the kerosene and traces of oil in a trichlorethylene or perchlorethylene degreaser. Bright nickel and chromium on brass, and copper and gold on aluminum were tested by this method in production quantities. This heating method produced blistered and peeled plating parts with defective plating adhesion that prior to test gave no visual indication of this condition.—INCO. 9605

2.3.7, 6.7.2

A Drop Test for the Evaluation of the Impact Strength of Cermets. B. Pinkel, G. C. Deutsch and N. H. Katz. Lewis Flight Propulsion Lab. National Advisory Committee for Aeronautics, Research Memo. No. E54D13, March 15, 1955, 8 pp.

Device for measuring impact strength of high temperature brittle materials at room and elevated temperatures. Extraneous energies such as toss energy are eliminated from the impact strength. Method consists of dropping a hammer from increasing heights so it strikes near free end of a cantilever beam specimen. Specimen support has a nickel-plated copper (Lektromesh) screen placed over specimen in vise and ⅛ inch nickel sheet electrode over the screen. Results of preliminary tests on effect of temperature on impact strength of several alloys (including a new cast nickel base alloy) and cermets are tabulated. Comparison is given between notched and unnotched specimens. Diagrams.—INCO. 9583

3. CHARACTERISTIC CORROSION PHENOMENA

3.7 Metallurgical Effects

3.7.3, 6.2.3, 3.2.2, 3.7.2

Formation of Graphite on the Surface of Steel During Heat Treating in Vacuum. E. Z. Graifer and I. V. Salli. *Doklady Akad. Nauk SSSR*, **97**, No. 4, 663-665 (1954).

Investigation of separation of graphite on surface of high carbon steel and of influence exerted by silicon on graphitization. Steel compositions studied were 1.50 percent carbon; and 1.50 percent carbon, 0.50 percent silicon. Kinetics of graphite separation as function of cooling rate and significance of holding temperature preceding cooling, are discussed. Experimental results are explained on basis of iron-carbon diagram, with special reference to effect of silicon. Photomicrographs, 5 references.—INCO. 9737

3.7.3, 7.4.2

High-Frequency Butt Welding of Pipes for Steam Coils. C. B. Clason. *Welding Engr.*, **39**, No. 3, 24-26 (1954) Mar.

Important component of the steam generator is the firepot or fire dome, which is made of heat-resistant Inconel sheet and lined with refractory material. A cone of Inconel sheet is welded together by means of the tungsten inert-gas process, using argon shielding gas and tungsten electrodes.—INCO. 9708

3.7.4

The Influence of Metal Structure on Properties of Investment Castings. N. J. Grant. *Precision Metal Molding*, **12**, Nos. 9, 10, 122-126, 92-95 (1954) Sept., Oct.

Based on lecture given to the Investment Casting Institute. Deals particularly with gas turbine blades cast in Stellite, etc. Effect of grain size and dendritic carbide networks; value of using hot molds.—BNF. 9744

3.8 Miscellaneous Principles

3.8.4, 6.3.17, 3.4.6

Low Pressure Hydrogen Solubility in Uranium. H. C. Mattraw. Knolls Atomic Power Lab. *J. Phys. Chem.*, **59**, 93-94 (1955) Jan.

The solubilities of hydrogen in uranium at various low pressures and at 295° C. using 10g. of powdered uranium are reported, and results are tabulated. For this low hydrogen concentration region the solubility is expressed by $S = K\sqrt{P}$, where S is in standard cc/10g. of uranium and P ranged from 26 to 150μ. Results showed the solubilities of hydrogen

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3.8.4, 6.3.20, 3.4.6

Solubility and Decombosition Pressures of Hydrogen in Alpha-Zirconium. EARL A. GULBRANSEN AND KENNETH F. ANDREW. Westinghouse Electric Corp. *J. Metals*, **7**, 136-144 (1955) Jan.

Thermodynamic information on the solubility of hydrogen in exothermic metals is limited. Thus, the over-all solubility decreased as the temperature rose, which suggests the heat of solution of hydrogen in the metal is negative yet the terminal solubility in the metal phase increased, which suggests an endothermic reaction. A thermodynamic analysis, therefore, was made of the several equilibria involved when hydrogen dissolved in the metal. Equations were derived expressing the solubility, terminal solubility, and decomposition pressures of hydrogen in terms of the heat, entropy, and free energy of solution of hydrogen in the given phase. The relations between the thermodynamic functions for the α-zirconium and δ-hydride phase were developed. The thermodynamic quantities were determined experimentally by the measurement of the decomposition pressures over a broad composition and temperature range. Two new methods of analyzing the experimental data were developed for determination of the terminal solubility. (auth).—NSA. 9427

3.8.4, 6.3.4, 3.2.3

Oxidation of Cobalt Metal. R. E. CARTER, F. D. RICHARDSON AND C. WAGNER. *J. Metals* (Trans. AIME), **7**, Pt. 2, 336-343 (1955) Feb.

By means of inert markers of radio-platinum, it has been shown that cobalt metal oxidizes by outward diffusion of cobalt atoms through the oxide. Oxidation rates have been measured at various temperatures and oxygen pressures and have been found to agree with the rates calculated from the Wagner equation and the authors' values for the diffusion coefficient of cobalt in the oxide. The distribution of radio-cobalt in growing oxide layers has been accurately measured and found to be different from that predicted from the Wagner oxidation theory. Attempts have been made to measure the change of lattice parameter of the oxide with composition. (auth.)—NSA. 9303

3.8.4, 6.3.6, 3.2.3

Process of Layer Formation in the Oxidation of Copper Under Low Pressure. (In French). FINN GRONLUND AND JACQUES BENARD. *Compt. rend.*, **240**, No. 6, 624-626 (1955) Feb. 7.

Type and duration of reactions investigated as functions of oxide formed during oxidation at low pressure. 2 references.—MR. 9428

5. PREVENTIVE MEASURES

5.3 Metallic Coatings

5.3.4

Recent Developments in the Electrodeposition of Nickel. E. A. OLLARD. *Ind. Finishing*, **8**, No. 81, 152, 154, 156 (1955) Mar.

Some of the present types of chromium and bright nickel solutions are described, and precautions required in their use.—BNF. 9656

5.3.4

Electrodeposited Nickel Coatings from Chloride and Sulphate Baths. E. RAUB. *Metalloberflache*, Sec. A, **9**, 88-93 (1955) June.

Experiments to determine influence of chloride on the process of nickel electrodeposition. Chloride and sulfate baths with boric acid additions and mixed baths were used: these contained 58.68 g./litre nickel and 24.4 g./litre nickel. Current efficiency was greater in chloride and chloride-containing baths than in sulfate solutions, and deposits were harder. Data on effects of evolution of hydrogen on hardness and structure of nickel deposits are included.—INCO. 9637

5.3.4

Electrodeposition of Lead-Tin Alloys. (In German.) E. RAUB AND W. BLUM. *Metalloberflache*, Sec. A, **9**, No. 4, 54-57 (1955) April.

Investigation of conditions of deposition of lead-rich alloys from the fluoborate bath.—BNF. 9648

5.3.4

An Experiment on the Effect of Type of Steel and Aluminium Content of the Bath on the Weight of Galvanized Coatings. N. B. RUTHERFORD. *Metal Finishing*, **1**, No. 2, 71-74 (1955) Feb.

Investigation of the effect of aluminum (up to 0.2 percent) in the galvanizing bath on zinc pick-up by two types of steel. It is shown that although aluminum is important (in general, the coating weight decreases with increasing aluminum up to about 0.1 percent, other factors such as the type of steel, cleaning and immersion conditions also have marked effects on coating weights. Work done by the Brit. Non-Ferrous Metals Res. Association. Based on information contained in Report R.R.A. 884, made available to B.N.F.M.R.A. members in July, 1950; reprints available as R.R.A.1044P.—BNF. 9667

5.4 Non-Metallic Coatings and Paints

5.4.5, 2.3.7, 1.6

Aluminum Paint and Powder. JUNIUS D. EDWARDS AND ROBERT I. WRAY. Book, 3rd Edition, 1955, 219 pp. Reinhold Publishing Corp., 430 Park Avenue, New York 22.

Book provides explanation of manufacture, properties and testing of aluminum powder with special emphasis on processes involved, color, brilliance, leafing, density, grading and handling as well as performance data and references. Chapter on aluminum paint composition gives information on varnish lacquer, silicone resin and bituminous vehicles, grade and amount of aluminum pigment and includes references.

Aluminum research laboratories tests, importance of film thickness, pigment concentrations, comparison with other paints, priming costs for steel and painting aluminum, magnesium, zinc, steel and aluminum alloys for marine service are subjects included in chapter on aluminum paint in protection of metals. Another chapter on special properties and uses of paint describes subjects such as reflectance, visibility, painting interiors and aluminum paint for oil tanks, structures, furnaces and radiators as well as water vapor transfer, resistance to sulfur compounds and electrical conductivity. Book is replete with tables, graphs and illustrations. 9575

5.4.5, 5.2.1

Polyethylene Tape for Pipe Coating. M. E. PARKER. *Petroleum Engr.*, **27**, No. 1, D28-D30 (1955) Jan.

Preliminary results of full-scale field test on polyethylene tape versus coal tar enamel pipe coatings are encouraging. Polyethylene has high volume resistivity (low conductance), high dielectric strength, almost negligible moisture absorption, and excellent mechanical properties, and is easily applied as a pipe coating material. Since current demands are very low, more reliable protection can be obtained by installation of constant potential system of cathodic protection instead of the conventional constant current system. Current source of low potential, but of intrinsically high current capacity, will result in self-regulating system. Use of zinc anodes as cathodic protection power sources also guarantees low-resistance grounding. Properly designed rectifier systems used for larger lines or higher resistivity soil, can give same protection. Illustrations, tables.—INCO. 9625

5.4.5, 5.4.6

Basic Essentials for the Reduction of Atmospheric Corrosion. FRANK RADECKE. *Corrosion*, **11**, No. 10, 437t-441t (1955) Oct.

A four phase plan used by a refinery to reduce atmospheric corrosion through the improvement of exterior coating protection is described. Included is a discussion of factors to be considered in setting up a maintenance painting program.

It was found that paint engineers will be concerned primarily with four matters: Selection of paint with respect to environmental severity, surface preparation, dry film thickness, and number of coats to be applied. It was found that the best combination of these factors must be determined by the engineer in order to ensure that the plant has adequate protection within the limits of economic practicability.

A plant specification standard prepared by an oil company is given. 9703

5.4.5 6.4.2

Protective Rubber Coating of Aluminium with Particular Reference to Spray Coating. (In German.) R. MOLL AND R. HEINRICHS. *Aluminium*, **31**, No. 1, 15-16 (1955) Jan.

Solution of synthetic rubber is sprayed on to a sand-blasted aluminum surface (article can also be dipped in the solution) and vulcanized: or thin sheet rubber can be placed directly over the sprayed layer and the article heated to 140-150° C. to vulcanize the sprayed layer. Examples of chemical resistance, mechanical properties and industrial applications are given.—BNF. 9609

5.4.7

Flow-Coating Aircraft Parts. R. C. BEAVER. *Org. Finishing*, **15**, No. 11, 17-19 (1954).

A description of the electrically driven monorail system used for passing aircraft parts through cleaning, pretreatment and flow-coating baths. The flow-coating apparatus is a low-pressure slushing arrangement in which the paint converges from both sides and the bottom from three bands of special nozzles. There is no atomizing action on account of the low pressure and the special nozzles.—RPI. 9789

5.4.7

Cement Lining of Water Mains in Situ. C. T. IDE. *Australasian Engr.*, 1954, 82-84, Feb. 8.

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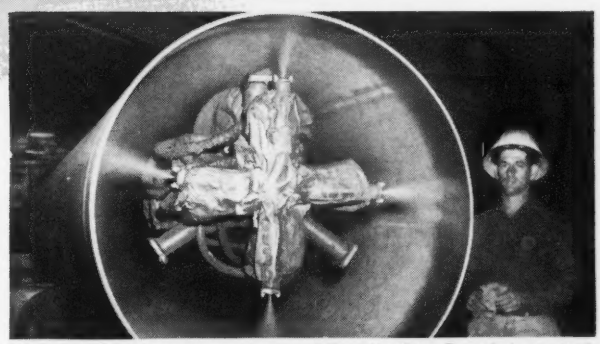
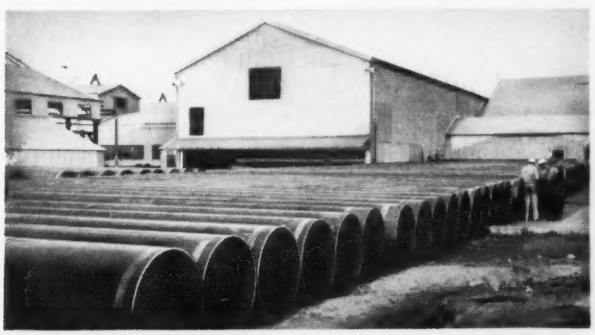


36" pipe to be laid by Transcontinental Gas Pipe Line Corp. being coated with *Copon*, containing Epon resin. *Copon* is manufactured by Coast Paint and Lacquer Co., Houston.



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action on cast iron and steel which manifests itself in metal pipes by the formation of tubercules. An aparatus was developed for cement lining the pipes that already were underground. This process is described.—INCO. 9718

5.4.7

Flow Coat Priming. C. O. HUTCHINSON. *Finish*, **11**, 43-44, 80-81 (1954).

Flow coating methods and equipment are discussed.—RPI. 9722

7. EQUIPMENT

7.1 Engines, Bearings and Turbines

7.1

High-Temperature Turbine Machinery for Marine Propulsion. T. W. F. BROWN. *Chartered Mech. Engr.*, **1**, No. 4, 162-203 (1954) April.

Surveys possible lines of progress in both steam and gas marine turbines, after reviewing recent land and marine installations. Includes some discussion of alloys for gas turbine blades, use of molten aluminum or magnesium as a blade coolant, and oil ash corrosion.—BNF. 9760

7.1

Today's Electric Motors—Special Report. J. I. O'CONNOR. *Power*, **99**, No. 6, 73-104 (1955) June.

Reviews recent motor-design changes and discusses types of motors available and their operation. Typical areas where major changes have occurred are in enclosures, rerating, and insulation. Enclosures of cast iron or stainless steel offer top corrosion resistance for chemical process industry applications. Epoxy and polyester resins and isocyanates are showing promise as motor insulations. Silicone rubber; phenolic resins; varnishes composed of epoxies, epoxy-alkyds, ester gums, polyesters and polyvinyls; and mica are other insulating materials. Bearings and lubrication are discussed. Tables, graphs, illustrations.—INCO. 9615.

7.1. 3.5.9. 4 2.3

Gas Turbine Combustion Development. K. L. RIEKE. *Blast Furnace & Steel Plant*, **43**, No. 3, 336, 338, 352-353 (1955) March.

Discusses the two basic gas turbine combustion problems — effective release of chemical energy by combustion of fuel within highly confined spaces, and high temperature corrosion of residual oil ash on turbine and turbine blade materials. Corrosion of W 8974, Inconel X, and Stellite 23 after 50 hours exposure in 1600° F exhaust gases of certain residual oils is shown. High corrosion rate is attributed to vanadium pentoxide and sodium sulfate formed during combustion process. Chart shows relative amount of corrosion expected from various fuel ashes.—INCO. 9659

7.7 Electrical, Telephone and Radio

7.7. 5.3.2, 6.4.2

Aluminium for Insulated Electric Cables. Aluminium Labs. Dev. Bull., Sept., 1954, 35 pp. Aluminium Labs. Ltd., Banbury.

Mechanical, physical and chemical properties of aluminum; methods of sheathing cables with aluminum, suitable protective finishes and installations; types of aluminum conductors, jointing and applications; aluminum wire armour to protect metal sheathed cables against mechanical damage; special types of cable and accessories.—BNF.

8. INDUSTRIES

8.5 Group 5

8.5.3, 7.6.6

Field Investigation of Corrosion in Alkaline Pulping Equipment. C. B. CHRISTIANSEN AND I. B. LATHROP. *Tappi*, **38**, 122-128 (1955) Feb.

Forces which cause corrosion in digesters. Recommendations for extending the service life of alkaline pulping equipment. Diagrams, graphs, table.—BTR. 9398

8.8 Group 8

8.8.5

Continuous Automatic Unit for Heat Treating Torque Converter Shafts at Chrysler Plant. A. R. ROBERTSON. Wayne Indus. Furnace Co. *Industrial Heating*, **22**, No. 3, 480-482, 484, 486, 488 (1955) Mar.

Description of compact heat treating unit embodying unit loading, heating for hardening, quenching, washing, rinsing, drawing, cooling and unit unloading. Unit may be used for carburizing as well as hardening. Rails, radiant tubes, support members and internal metal parts of hardening furnace are of 35/15 stainless steel. All metal parts within draw furnace, operating up to 1250° F., are type 430 stainless steel. Illustrations.—INCO. 9661

8.9 Group 9

8.9.2

Automotive Materials Changes. T. B. MERRILL, JR. *Materials & Methods*, **41**, No. 1, 83-88 (1955) Jan.

Chrysler engineers describe the big materials changes in 1955 models. Increased application of flame- and induction-hardened carbon steels replacing alloy steels in rear axle shafts, in fuel pump drive eccentric, clutch hubs and in connecting rods is reported. Hardenable cast iron alloy replaces chilled cast iron in the hydraulic valve lifter. Oil cooler passage previously fabricated of copper-nickel is now made of a copper-nickel clad steel. Galvanized and aluminized steel extends muffler life. In addition, a great deal of aluminum, functional rubber and plastics is employed. Nickel plating is used on headlight bezels and on bumpers. New process used first plates the bumper with ductile nickel then deposits, in same plating line, a bright nickel coat.—INCO. 9593

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TESTS PROVE it pays to specify coatings formulated with BAKELITE Resins

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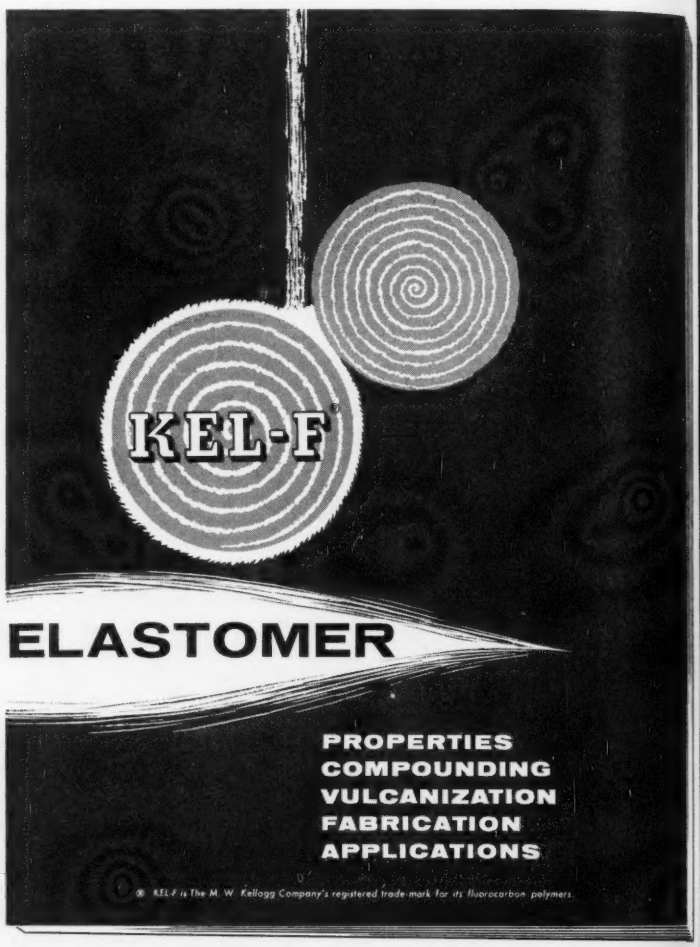

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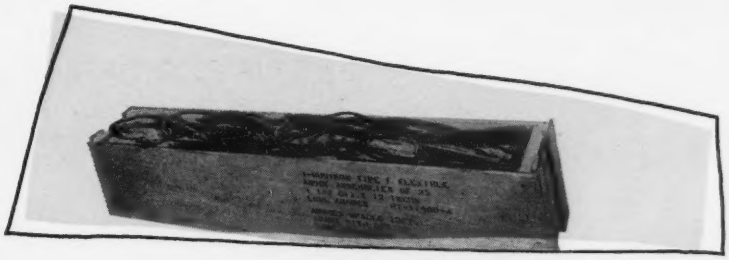

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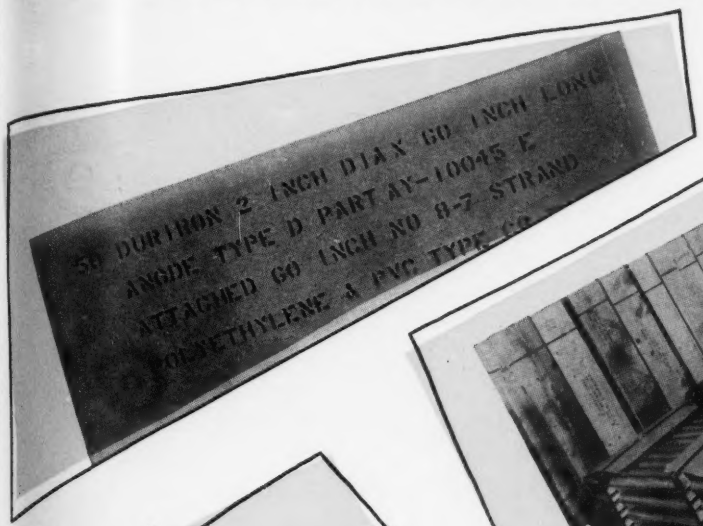

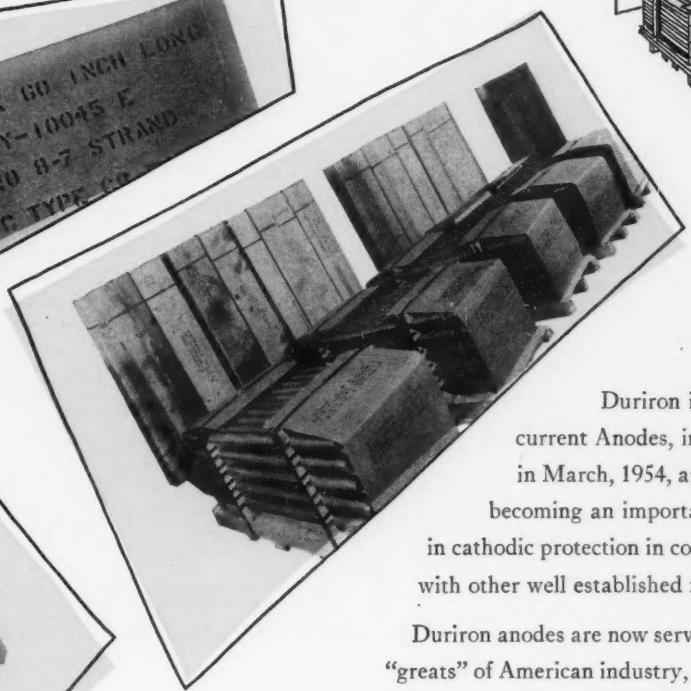

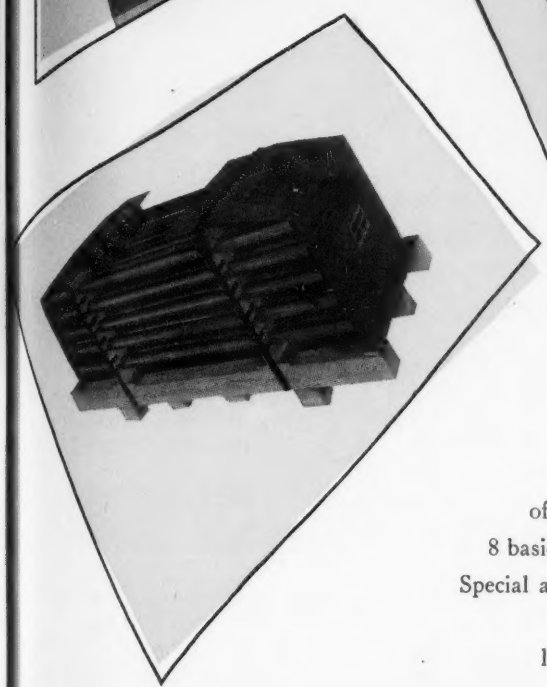

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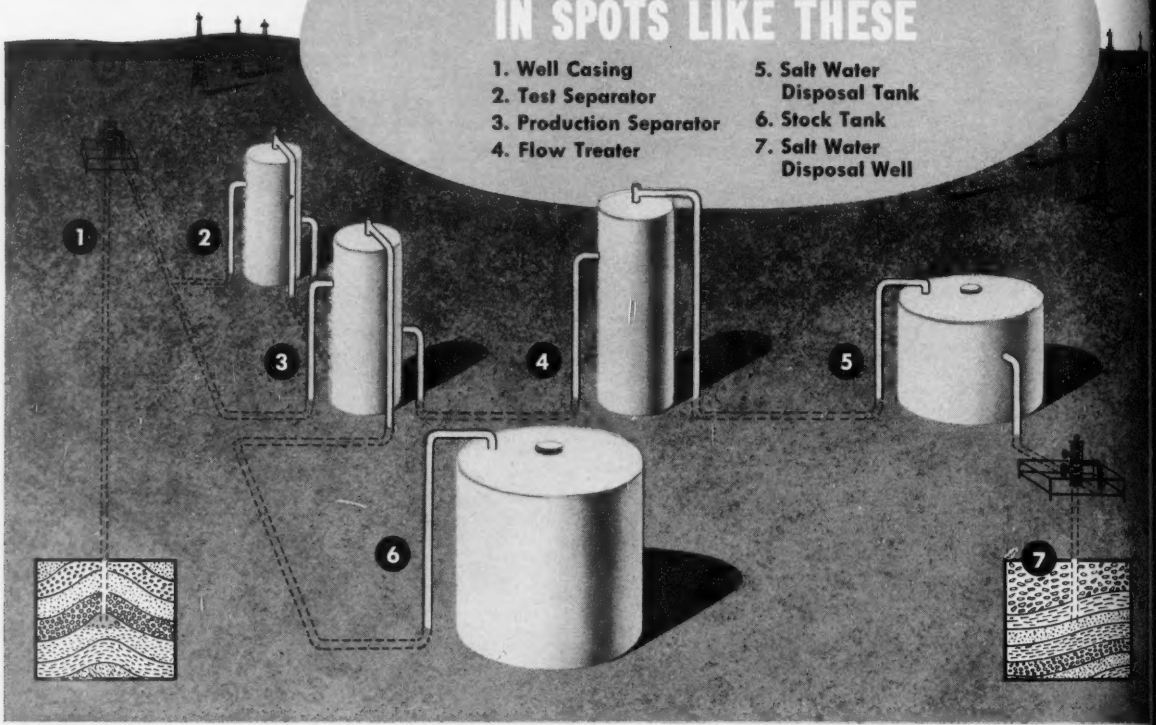

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